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PROJECT HARTWELL
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

A REPORT
ON
SECURITY OF OVERSEAS TRANSPORT

VOLUME I

of 2 volumes

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A REPORT

ON

SECURITY OF OVERSEAS TRANSPORT

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VOLUME 2

(of 2 volumes)

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PROJECT HARTWELL

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VOLUME II

APPENDIX C

SHIPPING AND PORTS

In a war against the U.S.S.R., the United States will find it necessary to move large tonnages of military and civilian supplies to overseas theaters without interruption. The critical lines of supply are assumed to be those to the United Kingdom, Western Europe, and North Africa. Further, it is assumed that the enemy can direct submarine and air attack against both the ships and the terminal ports of the Atlantic supply lines.

This Appendix discusses the present situation in shipping and ports, and proposes measures for providing successful delivery of supply overseas in the face of enemy action against either shipping or ports.

The elements of the problem are considered to be: (1) merchant ships; (2) harbor and port conditions; (3) interior transportation; (4) port-terminal facilities; (5) ship turn-around and cargo handling; and (6) labor and work methods.

I. MERCHANT SHIPS

A study of the inventory of merchant-class ships available to the U.S. for possible war-emergency use shows a critical lack of fast world-service types (see Annex D). The initial phases of a sudden war emergency would require maximum speed of supply to support military personnel moved rapidly into a war theater by sea and air. Only 13 per cent -- or 365 -- of the U.S. vessels presently available for war-shipping use are classed as "moderately fast" (16- to 17-knot sea speed). Liberty vessels and ships of intermediate speeds are not suited to the rapid-supply needs of modern war, nor do they embody flexibility and security from attack.

The planning estimate that assumes the present reserve fleet of Liberty-type vessels will supply any overseas shipping requirement for a period D + 23 months should be re-evaluated in the light

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of intelligence estimates of enemy capabilities and probable theters of operations.

The situation indicates a serious tactical need for new fast merchant-type ships possessing extraordinary characteristics with regard to mobility, self-protection, and cargo-handling equipment. To meet this need, the Hartwell group has envisaged a new fast ship with a sea speed of at least 20 knots, equipped with a large low-frequency listening array for torpedo detection, a helicopter weapons system, and an AA battery for use against low-flying planes (see Appendix B, Sections III and VI). It incorporates also the most advanced facilities and equipment for efficient cargo handling.

Many considerations support this concept of new fast merchant ships.

A. Military-Naval Considerations

The military aspects of the war-shipping problem involve security against: (1) surface men of war; (2) air attack; (3) submarines; and (4) mines. As developed in Appendix B, Section VI, security from attack improves as ship speed increases. Thus, fast ships are less vulnerable to the first three categories listed above; they also have an indirect advantage, by reason of their flexibility, against mines.

New fast ships equipped with improved detection devices and adequate weapons systems (see Appendix B, Sections II, III, and VI, and Appendix D, Section I) would have the following military advantages over the present slow ships.

1. Military operational support:

   (a) Fast ships can provide task-force support;

   (b) Fast ships are capable of rapid mobile support to any sea locale, e.g., were the Panama Canal damaged, fast ships are needed for satisfactory transportation over increased distances;

(c) Fast ships can be more quickly diverted if mine threat requires port dispersal.

2. Greater protection from submarine threat:

(a) Fast ships have greater flexibility in evasion tactics;

(b) New fast ships can provide a counter-threat against submarines;

(c) Fast ships are efficient for optimum convoy routing;

(d) Fast ships require fewer convoy-screen vessels.

3. Greater protection against air attack:

(a) Fast ships spend less time in the threatened area;

(b) The greater mobility of fast ships allows longer voyaging; thus they can take advantage of routes offering optimum safety from air attack.

B. Logistical Considerations

The present lack of fast cargo vessels places serious limitations on military-naval planning for prompt support of task forces overseas. Long, continuous pipelines cannot be sustained by slow, inefficient ships. Rapid supply is vital in the initial stages of war or even for a series of "Korean incidents". The need for fast ships is urgent now, especially since stockpile materials here and in allied countries are critically low. The ability to replenish these stockpiles in the early stages of a war is directly proportional to the speed of the ships employed, other factors being constant. The speed of filling a pipeline may mean the difference between maintaining an ally or losing him. When supply is critical in the early stages of a war, it requires only one-half the "dead" or ineffective volume to fill a 20-knot pipeline as is required to fill a 10-knot pipeline.

Thus, fast ships are capable of increased rate of supply with less fluctuations in flow. They provide, too, greater flexibility with respect to delivery locale. The logistic advantages of fast ships may be summarized as follows:

(a) Fast ships spend less time at sea;

(b) Fast ships wit! modern quipment spend less time in port;

(c) Fast ships require less time to fill a pipeline, as a result of (a) and (b).

(d) Fast ships have lower costs in manpower and expendable material, per unit ton delivered;

(e) Fast ships require less use of strategic war materials in construction, per unit ton delivered overseas.

C. Commercial Considerations

New fast cargo ships, whatever their war-emergency need, are primarily merchant vessels. They should possess not only good military characteristics, but should also be the best ships for foreign commerce and merchant marine service in peacetime.

Of the 1900 Liberty ships now on the books, probably only 1500 are serviceable and available; these are obsolete. A Liberty ship would require 134 days to make one complete voyage to the China-India theater -- or could make two such trips per year. Hence these Liberty vessels are best suited to short voyages where time in port is a major part of the over-all voyage cycle. Because of the emergency nature of their construction and the substitute materials employed, these Liberty ships are not adaptable to measures that might increase their speed. The reciprocating engines of these ships have critical speeds, and the welded hulls of commercial-grade steel would not stand the increased stresses and vibrations that would result from increased machinery power and sea speed.

Aside from the urgent defense needs, it is imperative that we build fast merchant-type vessels on a normal replacement basis if we are to maintain our competitive position in peacetime shipping. Nations such as the British and Scandinavians, whose life blood depends on their ocean shipping, have established a clear trend toward greater deadweight capacity per ship and toward increased speed. In this country, new fast ships have been built for special services such as the fruit trade and the bulk-ore and oil industries. Economic factors favoring this change to faster ships have been two: first, technical improvements in hull design and propulsion machinery (which lowers the cost of speed); and second, increasing labor costs for ship crews (which greatly favors fast turn-around). The economics of the trend has already been proved in a private industry (oil) as is shown by the following tabulation for the past 20 years.

Period	DWT Capacity	Speed (knots)
1920's	8 - 10,000	10 - 12
1930's	10 - 16,000	14 - 15
1940's	26 - 30,000	16 - 17

A study of fleet replacements of refrigerated vessels of the United Fruit Lines and the British-operated "Reefers" shows a comparable trend.

Unless new fast ships are built to provide for normal replacement, we shall continue to pay excessive subsidies to operate our obsolete vessels in competition with the new fast ships of other nations. We must therefore give intensive study and consideration to efficient propulsion machinery, good cargo stowage-handling characteristics, and low manning requirements.

D. Shipbuilding Considerations

The present international situation demands that we preserve our shipbuilding industry as an essential factor in the defensive scheme of the democratic nations.

Our shipbuilding industry has declined to a critical state: only one new ship of more than 5000 DWT has been laid down in U.S. shipyards since January 1950.

The world's major areas of shipbuilding are in Europe (United Kingdom), Japan, and the U.S. The sudden outbreak of war could immobilize the European shipbuilding industry, leaving U.S. yards as the sole reliance for providing ships for the Atlantic Pact nations. This fact requires that the U.S. industry be in an efficient state of readiness. A program for construction of new fast ships to satisfy military needs would serve to reanimate our shipbuilding industry.

E. Design and Characteristics of New Fast Ships

The new fast cargo ships should possess the greatest degree of flexibility with respect to economical high speeds (not less than 20 knots), cargo space, cargo-handling gear, world service, self-protection, and high-quality standardized sturdy construction. The vessel that will meet these general requirements will possess the following qualities, which, in turn, should be worked out on the basis of operational considerations.

1. Dimensions

The limitations imposed by berth depths, approaches, port-terminal characteristics, equipment and wharf areas in world ports suggest the following practical limits for overall dimensions:

Length: not greater than 550 ft., with 500 ft. optimum;
Beam: not greater than 75 ft., with 65 ft. optimum;
Full-Load Draft in Fresh Water: not over 30 ft., with 28 ft. optimum.

2. Net Cargo Tonnage

Net cargo tonnage should be not greater than 12,000 DWT, with 10,000 DWT optimum.

3. Holds

Holds should be arranged for fast cargo handling, with an optimum of 6 for a 500-foot vessel. The holds should be equalized with respect to cubic capacity.

4. Materials

The efficient use of materials will probably result in a ship possessing the maximum efficient speed attainable with a single screw. This means savings in critical steels and machinery and reduced cost and time factors in ship-building.

5. Power Plant

High-pressure steam type, probably not greater than 600-pound, total temperature not over 850°F, to minimize demand for critical metal alloys and specially skilled operators.

6. Hull

The ship should have a sturdy hull, be well compartmented, and be unusually maneuverable at operating speeds.

7. Self-Defense

Provision for a high degree of self-defense against submarines should be built into the vessel, including: a helicopter platform aft, with special cranes replacing masts to make this practicable; sonar; AA weapon locations; Holme device over the stern.

8. Cargo Handling

To achieve a high degree of logistical value and in-port operational efficiency, the vessel's cargo-working characteristics should complement the best port operations. Therefore careful consideration should be given to the following:

(a) Improve the hold's cubic equalization and between-deck clearances;

(b) Optimize distances from edges of hatch to ends and wings of holds (optimum distance 12 ft.);

(c) Remove permanent cribbing of cargo-hold obstacles such as pipes, brackets, valves, raised manholes, tank trunks, sloping deck surfaces;

(d) Remove excessive deck camber;

(e) Provide standard stanchions for shoring wings to take military deck loads;

(f) Provide system for fastening military cargoes to eliminate welding pad eyes and clips to deck on each voyage;

(g) Improve hatch covers and hatch beams by using pontoons, roller beams, roller covers, or similar improved hatch covering;

(h) Provide low-stowing level-luffing cranes in place of masts and Burton gear, on after-holds at least, so that helicopter blades will not be fouled; determine whether ship cargo cranes or masts and Burton gear are better (testimony of those using them states that cranes such as those found on the "Mulheim-Rhur" (see Schiffbau, May 1, 1938, pp. 145-148) outperform Burton gear by a factor of 2).

F. Summary

Whatever considerations enter into the design of new fast ships at this time, the following general criteria should be observed.

1. The ships should be as fast as practicable.

2. They must be superior in cargo-handling and cargo-space characteristics.

3. They must be built for world service.

4. They must possess a preplanned weapons system for a high degree of self-defense against submarines.

These new fast ships should be built now at a rate that should probably equal 150 per year. This figure, however, is based on replacement due to general obsolescence, and is responsive to major logistic estimates of the shipping needs of the democracies in wartime.

II. HARBOR AND PORT CONDITIONS

The major ports of the U.S. and of our European allies are vulnerable to air attack, although it is realized that prolonged heavy aerial bombardment is required to cripple large ports. Similarly, it is doubtful if major U.S. and European ports could be rendered permanently ineffective by such methods.

However, it must be assumed that the U.S.S.R. is capable of delivering an atomic weapon against ports at either end of the Atlantic supply route. Successful attack by relatively few atomic weapons could force the abandonment of any of these ports. It is essential, therefore, that harbor and port conditions in the U.S. and Europe be surveyed, with a view towards providing emergency plans to counter destruction of these facilities by utilizing alternative minor ports and mobile port units.

A. United States

1. Harbor Situation

The U.S. coast line may be divided into 3 principal ocean-shipping regions: Atlantic, Gulf of Mexico, and Pacific.

The Atlantic region has 21 harbors dredged to accommodate 30-foot draft vessels. Of these, Boston, New York, and Hampton Roads are suitable for deep-draft "troop" type vessels. It is reasonable to include the Canadian Maritime harbors of Halifax and St. John in this region. Halifax is suitable for deep-draft vessels.

The coast of the Gulf of Mexico has 14 harbors (most of them artificial) suitable for 30-foot draft vessels. Of these, none is suitable for deep-draft troop transports.

The Pacific coast has one artificial harbor (Los Angeles, breakwater-protected) and 3 natural harbors (San Francisco Bay and Puget Sound, landlocked, and the Columbia River estuary). The main Pacific harbors have numerous secondary harbors of which 12 are suitably developed for 30-foot draft vessels. All the major

Pacific coast natural harbors will accommodate deep-draft troop transports.

2. Port Situation

Forty-four U.S. commercial ports are suitable for war-shipping purposes (see map, Annex B). Ten of these constitute wartime combined ports in 10 principal harbors. Approximately 30 of the remaining 34 ports have not been used extensively as ports of embarkation in wartime. The proven capacities of U.S. major ports are shown in Table II-1.

The ability of minor ports to assume the load, should enemy action reduce or deny the effectiveness of major ports, is shown in Table II-2 which lists minor-port capacities as estimated at present and as they would be after 12 months' wartime operation without major construction of new facilities.*

Table II-3 shows a comparison of the relative capacities of major and minor ports in the various coastal regions. It gives also the constituted port potential as a means of estimating the ability of the U.S. to ship in support of overseas theaters. This table indicates the combinations of ports, major or minor or both, that would be required to meet a given supply requirement.

An analysis of the figures of Table II-3 shows that the major ports alone could support overseas, on a continuous basis, 5,500,000 troops at a maximum. The combined potential of major and minor ports as presently constituted will support 8,500,000 theater personnel. After 12 months, during which improvements have been made, U.S. port capacity can be expected to support 10,000,000 personnel in overseas theaters.

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* All estimates of U. S. major and minor port capacities have been made on the basis of using deep-water sea approaches and of using wharves already suitable for use, or wharves that can be made ready for use within 12 months without new initial construction or extensive rebuilding of existing unsuitable wharves.

The Atlantic ports as constituted can support 5,000,000 theater personnel. The Pacific ports, on the same basis, have a potential for supporting 2,800,000 theater personnel, while the Gulf port potential is 2,200,000. These figures assume no reduction of port capacities through enemy action. Port capabilities are limited by either port facilities or internal-transportation feeder support; this limiting criterion has been applied to all ports listed, under "optimum operation conditions".

3. Summary of the U. S. Port Situation

The crippling of the Port of New York on the East Coast would create a serious shipping problem in time of war if the overseas commitments were of the order of World War II maximum. New York shipped 37 million M/T of cargo or 29% of a total of 127 million M/T shipped from all ports during World War II. During the peak month (March,1945), New York shipped 1,670,000 M/T or 28% of a total of 6,000,000 M/T shipped from all U.S. ports during that month.

The Middle Atlantic hinterland of the U.S. is served by the ports of New York, Philadelphia, and Baltimore, with a combined export potential of 265 export sailings per month, nearly 40% of the total capacity of U.S. designated Ports of Embarkation. There are few alternate minor ports in the Middle Atlantic Coastal region. In the event of serious damage to the Middle Atlantic ports, the cargo shipments originating west of the Allegheny Mountains would have to be rerouted through the Gulf of Mexico ports; cargo originating east of the Alleghenies would have to be rerouted through New England and the South Atlantic ports where a surplus of minor port capacity exists. An alternate to this rerouting would be the use of expedient measures in the New York, Philadelphia, and Baltimore harbor reaches.

The present capacity of all minor ports, when compared to established POE's is two-thirds of World War II maximum for the

POE's. Within 12 months, and without new construction or extensive rebuilding, this capacity could be brought up to the World War II maximum for the POE's.

Capacity of the East Coast major ports is considerably in excess of East Coast minor ports. However, East Coast minor ports plus Gulf minor ports exceed the capacity of the combined East Coast and Gulf major ports. The minor ports of the Gulf have a considerable excess over normal wartime shipments from this region.

The West Coast major port capacity exceeds that of the minor ports. The port potential of the West Coast is concentrated in three areas -- Los Angeles-Long Beach, San Francisco Bay, and Columbia-Puget Sound. The crippling of Los Angeles-Long Beach would leave no alternates in that area. It would be difficult to cripple all the ports of San Francisco Bay, and even more difficult to cripple all the ports of Puget Sound. Loss of port capacity in the Southern California area would require rerouting of approximately 500,000 M/T per month through the Gulf of Mexico or through expedient port handling in San Francisco Bay and Puget Sound. Particular attention should therefore be given to providing alternate port capacity on the West Coast.

The port potential of the Gulf of Mexico offers the greatest dispersion possibility in time of war. The climate permits uniform efficiency the year around. The inland waterway routes offer an alternate transport system to Minneapolis, Chicago, and Pittsburgh during at least 8 months of the year.

Any plan for utilization of minor ports should contemplate the possible crippling of all combinations of major ports at different times and eventually the crippling of all major ports and some minor ports.

The proposed use of alternate ports and conventional facilities presently existing should not be regarded as the ultimate solution of this problem for wartime. A workable port can be improvised on any protected shoreline, arm of the sea, or estuary where suitable internal communications either approach the shoreline or can be brought to it. This makes the navigable rivers and bays of the U.S. seacoast adaptable to wartime expedient port operations.

Vessels anchored-off or moored to dolphins in a protected roadstead can load cargo from lighters, floats and crane barges at approximately the same rate achieved normally at U.S. port facilities. This, of course, requires double handling of cargo, but presents a problem no worse than is encountered in New York where double handling occurs in peace or war. The barges, cranes, and towing equipment that are needed in wartime can be balanced against the cost of proposed new wharf construction. With suitable cranes, scows, barges and floats, it is believed that ship turn-around time would not suffer in such a port operation. Experience in Rotterdam, Holland, has shown that 10,000 M/T cargoes are handled in this manner in 3 to 4 days of vessel time at fixed off-shore moorings.

The principal military depots of the U.S. are located inland from the coastal harbors, as is much of the industry engaged in supplying wartime export material. The allocation of major port hinterlands to include the tributary areas of minor ports should be made. In this connection, wartime export-freight origin and destination studies should accompany the plan for the alternate use of minor ports.

The necessary dredging of channel approaches, anchorages and berths at minor ports should be undertaken now to assure immediate occupancy and use in case of emergency. Rail communications feeding the satellite ports should be developed. Construction of rail trunk-line interconnections at advantageous locations, the enlarging of minor port backup storage and holding yards, improvement of intra-port rail circulation, and provision of proximity in-transit storage should be planned. Utilization of minor ports requires provision for adequate ship repair and bunkering. Consideration should be given to expedient loading from lighters to ships anchored-off in protected avenues of refuge such as rivers, bays, and estuaries, using DUKW's barges, lighters, cranes, "Rhinos", and similar types of expedient ship-shore cargo transfer equipment.

Mobile port organizations should be activated, equipped, and trained to operate in emergency ports. Trial operations on which to base SOP's in emergency locations and in the minor ports should be devised and tested immediately. Mobile port units, using expedient schemes, could continue to operate in marginal areas of heavily damaged major ports to salvage needed materials and supplies.

B. Foreign

The situation in harbors and ports at the eastern end of the Atlantic supply line has not been studied in detail since data on which to base an over-all survey were not available to the Hartwell group. However, there is reason to believe that the situation there presents an even more critical problem than that noted for the U.S.

Since a study of this problem requires a high order of liaison and concurrence among nations, any conclusions drawn on the basis of physical studies alone would be of little value. However, the foreign port situation is a vital factor in the Atlantic supply line, and should be surveyed.

A broad study of foreign port conditions should therefore be made, including estimates of wartime capabilities and proposed alternates and expedients for use under definite intelligence estimates and operational assumptions. Because of its relation to international strategy, this survey of the foreign-port war-utilization problem is properly the concern of a central coordinating body such as the Atlantic Pact nations.

III. INTERIOR TRANSPORTATION

The "pipeline" concept of defense transportation -- where hinterland industry supplies armies in the field -- becomes complicated when the pipeline must extend overseas and waterborne shipping is a major factor. The greatest bottleneck occurs at the shoreline, where transfer between water and land carriers must take place. To be successful, ports must constitute transfer points in a continuous supply flow, rather than act as reservoirs at the ends of shipping lanes.

Two factors mitigate against continuous supply flow under war-emergency conditions: trade-route practice and political considerations have established the major ports, not the minor ports, as principal transfer points in foreign commerce and inland transportation is devoted primarily to serving industry and domestic distribution, and only secondarily to foreign commerce. The first factor means that feeder transportation for alternate minor ports is not available if major installations are damaged; the second means that capacities of U.S. ports are regulated more by the rate of delivery of export freight to the ports than by the berths available for ship loading.

Of all inland transportation feeding ports -- railroads, highways, waterways, airways -- rail provides the principal reliable transportation of military and civilian supplies to U.S. ports.

Table III-1 shows that capacities of 19 out of a total of 35 U.S. ports are determined by export rail delivery rather than by port facilities. It is thus futile to develop ports in excess of the ability of interior transportation to deliver cargo to waiting ships or to handle that discharged by ship arrivals.

For example, it is estimated that the port of New York has 300 cargo-vessel berths and a daily rail capacity of 2210 cars for export (see Table VI-1). Tonnage the railroads can bring into New York could easily be handled by ships accommodated in 100 good berths. The 2210-car capacity is difficult to achieve because of lighter and tug boat limitations. Rail support is similarly a limiting factor in capacity of several other major U.S. ports (see Annex A). The lack of balance between port facilities and interior transportation feeders makes necessary careful study and planning if ports are to meet maximum war-shipping requirements. A well-coordinated national overseas movements control organization is a prime requisite.

In the past, it has been the practice to depend on railroads to supply overseas shipping. At peak capacity during World War II 180,240 export rail cars were unloaded at U.S. ports in one month, assigned as follows:

U. S. Army	91,058 rail cars
British	28,305
Russian	10,579
U. S. Navy	27,739
War Food Adm.	1,408
Lend-Lease	21,151
	180,240

During 1942-1943, when submarine sinkings ran as high as 1,000,000 tons of shipping loss per month, 33 per cent of the rail cars consigned to ports were held more than 10 days awaiting unloading. A critical disruption in internal rail transportation threatened as a result of this failure of ports to release rail cars on schedule. In turn, lack of rail cars caused shipping delay, since O.D.T. assigned only a certain number of cars for export purposes.

This experience indicates how serious a breakdown in overseas supply would result if, under present conditions, enemy action against rail centers or port facilities should disrupt rail movement. Such disruption could be minimized by use of minor ports and by development of a flexible system of alternate-port support.

To assure flexibility of supply, plans should be devised to provide rapid rerouting of rail freight to alternate ports. These plans should include wartime utilization of U.S. inland waterways as alternate feeders to ports (see Annex B).

The Mississippi inland waterway system could provide a down-current avenue of supply to Gulf ports, and could serve in conjunction with rail movements that at present limit Gulf port capacities. Were rail centers destroyed by enemy action, this waterway could supply Gulf ports from Chicago and Pittsburgh during eight months of the year. The industrial region of Birmingham, Alabama has access to the port of Mobile via inland waterways.

Inland waterway barges are well suited to handling war-packaged military cargo which would permit direct transfer of heavy equipment aboard ship without intermediate handling.

The Atlantic ports are connected by intracoastal waterways from Trenton, New Jersey, to Miami, Florida. This route is secure against submarine attack and provides a flexible alternate means of diverting export freight among major and minor East Coast ports. The ports of New York and New England are served by waterways extending to central New York and the Midwest via the N.Y. State Barge Canal and the Great Lakes.

In peacetime, highway transport handles approximately 50 per cent of the foreign commerce passing through port terminals, although the percentage is much higher for foreign commerce with origin or destination within the port contiguous area. Plans therefore need to be drawn for alternate extreme-emergency use of highway transport for short haul (i.e., 150 miles or less) to ports.

When fast ships are used on war-shipping routes, it is practicable to coordinate them with air shipments. Express-type freight, to be carried as deck or top cargo, is flown to the nearest airfield and moved by fast highway transport to shipside just prior to sailing. This cargo could be stowed on hatch covers and, on arrival, removed first for air transport to destination. This practice would require use of special knockdown water-tight containers designed for stowing aboard cargo aircraft.

The situation prevailing for U.S. interior transport is duplicated at the destination ends of the ship lanes. The ability of ports in the United Kingdom, Western Europe, and North Africa to receive and handle supplies and to ship them to war theaters presents a complicated problem.

There is great opportunity for alternate planning in the United Kingdom, where the extensive railroad net meets the sea coast at many points. This, together with the many coastal indentations and the multiplicity of minor ports, offers considerable flexibility in getting supply ashore and transported inland.

In Western Europe, from the Pas de Calais northward, the situation is unfavorable for landing deep-draft vessels except at established ports. Transportation except from these major ports is lacking and this, together with the lack of natural harbors, makes shipping to Northern France, Germany, and the Low Countries difficult in wartime.

The situation is somewhat more favorable on the French coast along the Straits of Dover south to the Bay of Biscay, and the interior transportation from this region is better suited to unloading supply from ocean cargo vessels by expedient port measures.

The ports of Europe and Africa along the Mediterranean are favorable for war shipping movements; the North African interior transportation facilities are poor but the European lines are adequate to utilize the physical capacities of the ports.

Summary

The capacity of a port at either end of the supply line is no greater than the ability of interior transportation to handle supply to the port or to transport it inland. In nearly every case surveyed, the limiting criterion in determining port capacity was the interior communication system. If war shipping is to present a maximum integrated movement, plans must be drawn to provide transport service compatible with port capacity for all major and minor ports that will be used.

The planned emergency use of minor ports requires that immediate attention be given to providing adequate supply to alternate facilities. This requires a whole new scheme of routing export freight including new trunk line interconnections between established holding points and major-port trunk lines. The ability to divert export freight on short notice to any alternate port necessitates smoothly functioning plans long before the outbreak of war. Such a plan should contemplate the full utilization of inland waterways, intracoastal waterways and canals. A flexible system of transfer between rail and barge lines is needed to ensure uninterrupted supply flow in the event of war damage to primary rail lines. Needed also is provision for efficient exchange between truck, rail and barge lines. Coordination of air-sea shipments should also be studied.

IV. PORT TERMINAL FACILITIES

Port terminals in time of war must be regarded not as the ends of two systems of transportation, but rather as transfer points in the overseas supply pipeline. Port terminals in the past have proved serious bottlenecks in the supply line, affecting not only ship turn-around,but the number of ships required to man the overseas supply routes. Thus, the number of ships that must be built to offset demonstrated port-terminal inefficiency affects our whole war economy and war effort.

Compared with any other phase of U.S. industry, port-terminal operations are inefficient and outmoded. The major U. S. waterfront terminals are operated by local port authorities under municipal and state government ownership and control. Local concepts of the problem have dictated varied solutions, and, as a consequence, a large percentage of our port terminals is functionally poor, obsolete, and structurally unsafe. The proper selection and rehabilitation of existing U.S. port-terminal facilities is essential if the needs of a future war are to be served.

Most of our East Coast port facilities were built 40 or 50 years ago for vessels of the 19th century, as were most of those of San Francisco. In consequence, East Coast ports, which handled more than 50% of World War II shipping, were operationally inadequate to serve modern dry-cargo vessels on a high utilization basis.

The Gulf port facilities are better suited to serve modern vessels, not by reason of their modernity but because of better functional characteristics. These facilities were built originally to handle cotton, which provided a large cubic capacity. Also, the natural harbors of the Gulf favored construction of marginal quay-type wharves.

With the exception of San Francisco, the West Coast ports are the most modern and functionally adequate general-cargo terminals in the U.S. These facilities are well adapted to the high-output, work-managed operations so necessary to improved vessel turn-around in wartime. The facilities of Long Beach-Los Angeles are excellent examples of flexible general-cargo terminals.

Certain inadequacies of port terminals stem from the increase in ship cargo capacity during the last 50 years; this increase has come not by progressive evolution but as a result of wartime construction. During World Wars I and II, whole generations of new ships were built in record time to replace the older vessels that were sunk. Ship capacity nearly doubled in World War I, and the process was repeated in World War II. On the other hand, the East Coast terminals that were built prior to World War I have remained in use and are thus much too small to handle the full cargo of a modern vessel.

For war use, only those U. S. port terminals possessing sufficiently sound characteristics should be selected. These should then be renovated for unified, rapid, mechanized shiploading operations. Further, the characteristics of a national terminal capable of supporting high-speed ship-loading operations and fast transfer between ship and interior transportation should be developed as a vital factor in efficient overseas supply.

There are no established and accepted standards and codes of construction and functional characteristics for U.S. general-cargo terminals. Studies of port-terminal operations by the Maritime Commission (1946 and 1947) indicate that certain fundamental characteristics are desirable if facilities are to complement modern ships and to provide fast, efficient operation. These characteristics will be described in order to establish a basis for selecting suitable terminals and for adapting existing wharves for contemporary needs.

The substructure of a wharf is substantially the same for bulk cargo, special-purpose and general-cargo facilities. The superstructure determines the wharf's operational use. Solid-fill wharves are desirable for a general-cargo superstructure, while wharves capable of sustaining live loads of 600 pounds per square foot are necessary.

The superstructure of a general-cargo terminal should be constructed to enclose and support a controlled cargo-handling work process. The facility, so far as a single berth is concerned, should be a single self-sufficient unit capable of serving the largest modern dry-cargo vessel. Because ship characteristics differ, and because optimum work processes have not been established, the physical characteristics of the terminals should embody a high degree of flexibility.

It was learned during World War II, through the introduction of cargo-handling equipment -- power conveyors, fork-lift trucks, tractor cranes, and industrial tractors and trailers -- combined with controlled industrial-engineered work processes, that cargo could be handled faster, with less manpower and at lower cost than formerly. The work processes that can be developed to utilize mechanical materials-handling equipment, in conjunction with engineered operations, is well suited to terminals possessing the following notional characteristics.

A. Wharf Deck Area

A single self-sufficient unit of the ideal general-cargo terminal requires a wharf area approximately 600 feet long by 300 feet wide. This unit is most practically suited to the marginal or quay-type wharf arrangement. It is submitted that the quay-type wharf arrangement is best because it offers maximum flexibility. It lends itself to planned-work methods; it permits looping of feeders; and it has land access on three sides. The distance from center of gravity of terminal work process to transportation access and storage support is shorter. It is easier and more economical to achieve unrestricted deck loads. Maintenance dredging is easier. There is less interference with stream currents, less interference in lightering and off-side loading operations from barges. Finally, shiphandling and maintenance problems are simpler. When, for some reason due to local conditions, the construction of at least two of these units on a quay line is not feasible, a double-finger pier arrangement of two of these units placed back-to-back is an acceptable alternate. Single piers are not considered practical for general-cargo terminals.

B. Wharf Deck Layout

The wharf deck of the quayside terminal unit is composed of four principal elements: a shipside apron, a single-story transit shed, a rear loading platform, and a rear "farm" area.

(1) Apron. The wharf apron is the shipside work platform. It should be constructed flush with the transit-shed floor. It should be constructed to sustain a 600-pound per

square foot live load and Coopers E-60 rail loads. It should not be less than 44 feet wide in the snow belt nor less than 49 feet in warm climates. Space should be provided on the apron for the rail of a half-portal cargo crane and three rail tracks on the multiple-unit quayside arrangement. The centerline of the shipside rail should be 14-1/2 feet from the face of the wharf fender system, or 9 feet from the outside of the string piece to the outer rail of the shipside track. The rail crossovers should be approximately 100 feet from each end of the transit shed. The wharf deck should be placed above mean low tide in accordance with the following table of practical distances.

Average Tide Range (feet)	Elevation of Wharf Apron Deck Above M.L.W. (feet)
12	+ 17
11	+ 16
10	+ 15
9	+ 15
8	+ 15
7	+ 15
6	+ 14
5	+ 14
4	+ 12
3	+ 12
2	+ 12
1	+ 12
0	+ 12

The apron deck should be of a smooth hard durable pavement, with care given to minimizing unevenness of track work. A grade of + 1 should carry across the apron to the shed face. Proper drainage should be provided, with radiant-type snow and ice removal in cold climates.

(2) Transit Shed. The ideal transit shed for wartime operation is a one-story structure that can develop the bale cubic of the largest dry-cargo vessel and provide adequate working aisles. The interior floor dimensions of the shed should be(optimum) 550 feet long and 200 feet wide, with limits of 500 to 600 feet length and 200 to 175 feet width.

This contemplates an effective floor-area utilization of 60% with average 12-foot stacking height. A vertical clearance, below trusses, of 20 feet should be provided, based on cargo-handling-equipment stacking capabilities. A clear span with no interior columns should be sought. The presence of interior columns in a transit shed places obstacles to terminal operations, which, over the life of the terminal, far outweigh the extra cost of long spans. Columns reduce the flexibility of operational planning. Interior columns restrict preplanning of sheds to accommodate vessels with various hatch openings.

Sheds should be fire-resistant. It is possible to build them of fire-proof construction, employing thin shell concrete construction -- a small difference in cost over conventional fire-resistant construction. The minimum height of shed cargo doors should be 16 by 18 feet clear opening. These doors should be spaced so as to be no greater than 36 feet O.C., with alternate interchangeable dead panels. If alternate spacing is not used, 30′ O.C. is regarded as optimum spacing. If operationally desirable, the alternate dead panels could be constructed to swing up on hinges to present a continuous opening except for wall columns along the apron. The floor of the pier shed should normally be flush with the apron, and 3.75 feet above the depressed rear area. It is advantageous to extend the + 1% grade of the apron through the shed from the apron to the rear platform at + 0.75 grade, so that excavation at the rear loading platform is minimum and grades from rear areas to apron between sheds are kept small.

The surfaces of the shed floor should be smooth-paved with durable paving -- preferably asphalt concrete wearing surface -- to carry 500-pound per square foot live load and the heaviest highway-vehicle concentrated loads. Care should be taken to eliminate pavement joints which interfere with caster-wheeled vehicles.

Provision should be made to support a crane girder above cargo-door portals. Exterior columns and footings should be constructed to support semi-portal gentry-type cargo cranes.

(3) Rear Platform. A freight platform 16 feet wide should extend along the rear of the transit shed for the purpose of unloading freight from rail cars and trucks. This platform should be flush with the transit-shed floor and 3.75 feet above the top of rail of parallel rail tracks. This platform should be served by doors with not less than a 14 feet wide by 12 feet high clear opening in the rear of the shed. The center of platform and cargo-door openings should be on a line across the shed. Access to the ends of the platform should be provided by ramps at the ends of the sheds.

(4) Rear Area. The 44 feet of unit width remaining at the rear of the shed is depressed 3.75 feet below the rear-platform elevation and is intended to contain two parallel rail tracks and room for tractor semi-trailer trucks to back to the platform. It is assumed that two rail tracks will be provided for multiples of 3 terminal units, and 3 rail tracks for more than multiples of 3 units. A discussion of multiple units in quay-type arrangements will develop the reason for the increased trackage.

An open area, usually referred to as the "farm" area, is required to support a terminal. A large farm area is desirable, and the minimum per wharf unit should be equal to the 300 by 600 foot area of the unit, up to multiples of 3 units. Beyond this, open port area at the rear of the sheds should be increased in the ratio of one-half unit area per unit involved.

C. Terminal Arrangements

The individual terminal unit that has been discussed, while operationally self-sufficient, is expected to be constructed in multiples of at least two units. Pairing of terminal units affords flexibility for operations, management and future changes. Marginal wharf units should be spaced along a quay in multiples of 3 units each, separated by 100 feet. Each 3-unit multiple should be separated by an open berth 600 feet long through which rail tracks pass into the rear areas. The 100-foot separations provide individual access from the rear to the aprons, while the 600-foot berth provides front-to-rear rail access as well as vehicular access. A section of 6 marginal units appears to be an ideal arrangement for a marginal quay. If this is increased, the matter of rail holding yards and adjacent classification yards in the port terminal rear areas complicates the problem. In preparing a master plan, the land area dedicated to the port should be an area equal in depth to the berth length for a section of 3 units; for 6-berth units, the length should equal the quay length divided by the number of terminal units, or 800 feet. The added width is required to provide additional rail tracks, road width, vehicle park areas, etc.

If it should be decided to build a finger pier by placing units back-to-back, a less efficient arrangement results. The pier so formed provides 3 berths, only two of which are workable. If the pier is 2 berths long, 5 berths are provided with only 4 effective berths multiplied by an interference factor of about 0.8. Theoretically, a finger pier should be trapezoidal in shape, so that additional feeder flows are provided for the outer berths.

No matter how well a finger pier is arranged, the fact remains that the center of gravity of each separate work process and the combined operation of the several units are farther removed from the shore side of the shore-ship transfer operation. In the finger pier, supply flows from the shore are in effect "reciprocating", while the marginal pier permits looped or "rotary" flows. The finger pier lacks the flexibility of the quay arrangement.

Summary

Plans for rebuilding or replacing existing wharves in U.S.

ports, and standards for construction of emergency war facilities, should be prepared, based on the proposition that the most modern concepts of port operations will be used in wartime regardless of local custom. The makeshift port terminal structures intended for "far shore" construction by C.E.C. of the Navy and Army Corps of Engineers should be revised to allow maximum flexibility and output capacity.

The wartime port terminals must be selected for their ability to use the optimum work processes for loading and unloading miscellaneous cargo. The adequacies and flexibility of the terminal can be assessed by comparison of its characteristics with those listed for a notional terminal. Expedient equipment and operations methods designed for use at alternate ports in the event that established terminals are destroyed can be used now to increase peacetime output. These mobile port units will also provide extra equipment and trained personnel for operating war-damaged or makeshift ports in various theaters of operation.

V. SHIP TURN-AROUND AND CARGO HANDLING

The number of ships needed to sustain an overseas military operation is determined by the least time in which vessels can make round-trip voyages. Turn-around time, or round-trip voyaging time, depends on two factors: the speed of vessel, and the time spent in port loading and discharging cargo. The speed of the vessel is established when it is built. The time spent in port depends on a complexity of factors: work handling, construction of cargo holds and lift gear, and efficiency of port terminals. A ship turn-around cycle is composed of four segments:

(1) Time in home port working cargo, plus non-effective repair time;

(2) Voyaging time to destination;

(3) Time in destination port working cargo, plus repair time;

(4) Voyaging time to home port.

The non-effective time in peacetime is that required for normal repairs and annual overhauling; the total of this is usually equal to 20 or 30 days per year. However, during war this non-effective time increases for various reasons; these are best indicated by Tables V-1 and V-2, covering operations of Army and Navy vessels during unfavorable and favorable periods of World War II.

The number of ships available for U.S. war shipping at present together with their speeds is shown in Table V-3. It will be noted that approximately 1900 vessels of 11-knot speed comprise approximately 70% of the total available tonnages. Since the slow speed is built into these vessels, the only chance of improving turn-around time is to reduce time spent in port.

Present Army Transportation Corps planning assumes that a vessel engaged in continuous overseas supply will spend 30 days of each voyage cycle in port, with no distinction made between fast and slow vessels. Loading and discharge of cargo at both ends of the run occupies approximately 20 of the 30 days of port time.

During a favorable period in World War II, the average time spent in working cargo in U.S. ports was 7 days per vessel. The best average commercial port performance in the U.S. during the war was 5 days per vessel. The average cargo-working time in U.S. ports was greater than in European ports (see Tables V-4 and V-5).

Two primary factors allowed established foreign ports to outperform U.S. ports: the first was better cargo-handling equipment; the second was better functional characteristics of the port terminals. Foreign ports were able to use fast cargo cranes to complement ship gear, and these proved well suited to handling military cargo. They also provided good floating cranes for cargo and heavy lifts. None of this foreign cargo-handling wharf-crane equipment is available in the U.S. The commercial floating-crane equipment is of poor quality compared with that of foreign ports and is inadequate for fast wartime operation.

While the cargo-handling gear on U.S. ships is superior to that of the average foreign vessel, both the U.S. and foreign vessels must carry their own gear to handle cargo in U.S. ports; in normal times vessels do not use their own gear in ports outside the U.S. because, in many foreign ports, shoreside cranes are avilable. Despite the specialization, our vessel gear is not good enough; in fact, the best gear on the most modern foreign vessels outperforms the best gear on U.S. vessels. For example, in the opinion of some contracting stevedores, the level-luffing cranes on the Hugo Stinnes Line outperform Burton-type gear on U.S. vessels by a factor of 2.

Cargo Handling

The weakest link in the U.S. overseas transportation system in both peace and war is the transfer of miscellaneous general cargo between vessels and land transportation at U.S. port terminals.

Our system of materials handling is outmoded, costly and slow. Our failure to improve waterfront ship-shore exchange operations has reduced our intracoastal shipping and has placed our merchant marine in an embarrassing competitive position.

During World War II, the Armed Forces introduced mechanical handling equipment into the waterfront industry to the extent of using fork-lift trucks and pallets and portable roller conveyers. The basic scheme of operations, however, remained substantially the same, and the output per berth in U.S. ports varied widely as to tons per man-hour rate, time on berth working cargo, and cost per ton of cargo handling. The wide variation may be attributed to the great diversity of uncontrolled work processes including unsystematic use of mechanical equipment, and the extreme variance in terminal characteristics. Thus, even mechanized operations were inefficient.

The cargo-handling problem is influenced by ship cargo space and hoisting characteristics, by wharf and terminal characteristics, and by labor work methods (see Sections IV and VI). Improvements in cargo handling at U.S. waterfront terminals devolves on the engineered use of mechanical equipment and on technically controlled labor processes, all designed to transfer materials efficiently between two types of transportation. A prime requisite is that all U.S. war-shipping port terminals be under responsible, single-unit operational control with each terminal functioning as a decentralized unit under a central coordinated port management. In addition, the following are needed.

(1) Central Terminal Management and Control:- The terminal, the surrounding open storage areas, rail-car shifting and unloading, use of mechanical equipment, stevedoring, vessel berthing and terminal management should be under a terminal superintendent. Each terminal should have a central equipment pool, and the equipment should be allocated and used on the basis of process studies and engineering determination.

(2) Coordinated Movements Control:- A close coordination should exist between terminal superintendents and a central movements control and planning organization. Pre-stowage plans should be prepared and furnished sufficiently in advance of ship-working operations to permit pre-planning of terminal space and pre-organization of methods.

(3) Mechanical Handling Equipment:- Level-luffing wharf apron cranes -- track-mounted where practicable, otherwise portable rubber-wheeled or "cat" mounted -- to assist ship gear should be provided. Floating self-propelled level-luffing cargo cranes should be furnished for working off-side from barges, lighters, etc. The terminal's mechanical equipment should include power-driven and gravity-roller conveyors, portable cargo elevators, fork-lift trucks, tractor cranes, industrial mules, and trailers

and elevating loaders. In addition, cargo stowers, spud-equipped floating aprons, and cargo escalators should be developed as required.

(4) Packing and Packaging:- An Armed Forces joint committee for standardization of packing and packaging should be established to control these phases of export shipments, and to standardize design of knock-down containers and pallets (see Section III).

(5) Industrial Engineering:- Terminal operations and vessel stowage should be under the single technical control of industrial engineers who determine standard operating procedures, work processes, and maximum utilization of equipment for each terminal.

(6) Training Berths:- In conjunction with (3) and (5), training berths should be established in each port to train longshoremen in effective use of this equipment under industrially engineered work methods.

Summary

Improvement in ship turn-around will result only from insistence at high level on mesurable improvement in cargo handling, which in turn depends on efficient management, engineered operating procedures, improved labor practices, use of mechanical equipment, and functional terminals.

Target total port time for a vessel during war should be limited to 6 days in U.S. ports and 5 days in foreign ports, if convoy operation prevails.

VI. LABOR AND WORK METHODS

The longshore labor situation in the U.S. is not favorable to improvement in vessel loading rates. Longshore labor here operates on a casual employment basis under local (AFL and CIO) and international (ILA) unions. Longshore labor is controlled by local union representatives who, through hiring-hall practices, exercise jurisdiction over the workmen and fix the rates at which cargo is handled. At the local level, every effort is made to sustain a large number of union members. This strategy spreads the work from day to day and keeps a maximum number of union personnel employed. Although hourly rates are high, annual incomes are low because of the intermittent nature of employment. Long periods of control by dubious leadership has depressed the quality of longshore labor* to the point where it is not adaptable to new work methods and is resistant to the introduction of modern mechanical handling equipment. In consequence, the growth of the U.S. maritime industry has been retarded, and the industry must be subsidized to offset the induced inefficiency. Rates of cargo handling are slowed to the point where a vessel is required to remain in port a week or ten days to discharge a full cargo. These practices carry over into wartime.

The urgent need for efficient utilization of manpower and for rapid cargo loading in wartime demands a high degree of mechanization and the decasualized employment of skilled equipment operators.

There are certain localities where labor leadership is not so vigorous in its opposition to the introduction of new methods of cargo handling. These localities are, in order: Tacoma, Washington; New Orleans Army Base; and Mobile, Alabama State Terminal. These terminals offer a suitable environment where trial cargo-handling berths could be established under joint military supply technical supervision. Here procedures could be devised under time-study and work-management methods. The operating procedures so established could be used initially to train military port units. Later, the established work methods could be transferred to civilian groups under on-the-job training programs. During World War II, a work methods revision program was undertaken on an experimental basis by the Navy Bureau of Supply. The

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* Recent surveys conducted on the New York waterfront showed over 30 of longshore labor to be aliens.

results of single-operation trial experiments proved that dense cargo could be loaded 75% faster at 100% saving in man-hours in certain holds of conventional ships. It proved, too, that LST's could be loaded in one-third the time, with labor productivity increased by a factor of 4, when engineered methods were used. These results were achieved under conditions similar to those of conventional methods.

In 1944, the Navy Supply Depot at Gulfport, Mississipi, conducted experiments in loading 3 LST's alloted similar cargo. The three cases tested were: (1) conventional stowaged by normal stevedoring methods, (2) cargo 50% palletized, (3) cargo 100% unitized using engineered cargo handling. The results are shown in Table V-1.

The military services have made studies of cargo handling at selected privated terminals. An analysis of these studies indicates the expected magnitude of man-hour rates, tons per hatch-hour, and days required for working a ship (see Table VI-2). The rates shown are for existing vessels with conventional gear and current work methods. These have been compared with rates for existing vessels supplemented by new-type shore cranes and work-managed mechanized terminals. An estimate is also made for new vessels with improved hold characteristics and new cargo gear. These figures attempt to forecast the expected performance of working cargo at conventionally operated terminals and at terminals with new operational methods and employing wharf cargo cranes.

In preparation for war, the Armed Forces are obliged to activate and to train mobile overseas port-operating units at every level -- from port headquarters to hatch gangs. It is necessary that enough units be activated to conduct experimental cargo-handling exercises of a new character in order to establish the pattern for fast ship turn-around both in the U.S. and overseas.

Summary

War manpower utilization studies of waterfront labor, as it affects war shipping, should be made. These studies should contemplate the more effective use of manpower in cargo-handling, particularly in connection with mechanical equipment. Every attempt should be made to ensure a stable longshore labor element, with decasualized employment and with pronounced individual work incentive. Consideration should be given to more direct control of waterfront by terminal management.

The materials-handling techniques perfected elsewhere in U.S. industry should be adapted to and utilized by the marine industry. Civilian port procedures should be adjusted to these new operations, the transition being made by initial use of military units for training purposes.

VII. CONCLUSIONS

A. New Fast Ships:- New fast ships should be built now at a target rate reasonably estimated at 150 vessels per year. These new ships should be as fast as practicable, constructed for world service, fitted with new types of cargo-handling gear and hold arrangements, and equipped with improved listening gear and a weapons system.

B. Port Dispersal:- Immediate action should be taken to place minor U.S. ports in a state of readiness to handle war shipping in case any major ports are rendered ineffective. Studies should be made of port conditions in allied countries in order to estimate their wartime capabilities. Cooperation of Atlantic Pact nations is needed to ensure sufficient emergency ports in condition to support war shipping.

C. Interior Transportation:- Interior rail transportation nets supplying export freight should be readjusted to permit rapid rerouting of shipments to or from any combination of ports and to or from any hinterland locale. Plans should be made to utilize inland waterways to improve port capacities and to provide alternate emergency avenues for export freight.

D. Port Terminals:- Only those U.S. port terminals with sufficient sound characteristics should be selected for wartime use, and these should be renovated to complement modern vessels. The characteristics of a notional terminal to support high-speed ship-shore transfer operations must be developed as a standard.

Mobile port units should be organized and developed. They should be equipped with modern cargo gear to operate ports under war-damage conditions in either the U.S. or an overseas theater.

E. Ship Turn-Around and Cargo Handling:- Improvement in port loading and discharge times by a factor of two could be achieved using the best practices now in existence. This would permit fast vessels operating between the eastern U.S. and Europe to average twice the tonnages obtained under the best performance in World War II with Liberty and Victory vessels. The greatest savings in overseas-supply transportation can be achieved for the least cost in materials, manpower and money by improving the system of cargo handling in ports.

Extraordinary measures should be taken to reduce ship turn-around time by mechanizing cargo-handling operations at port terminals, by using skilled labor, and by standardizing packing and packaging of supply for overseas shipment.

Cargo-handling operations in all military-base port terminals should be mechanized at the earliest practicable date. The transition now would form the basis for perfecting an engineered work system intended for wartime use.

F. Labor and Work Methods:- The longshore labor situation should be thoroughly studied and reappraised with a view to instituting a system of continuous employment in wartime. A plan for eliminating the hiring-hall and the gang system should be in readiness for implementation in case of war. Training of waterfront labor in use of mechanical cargo-handling equipment under engineered work methods is necessary.

Table II-1

MAJOR U.S. PORTS
CAPACITY FOR WAR SHIPPING

Port	Maximum M/T Shipped from Port in Any Month during WW II	Sustained Daily Rail Capacity 30T Cars	No. Berths 500' by 30' Depth	Max. No. Sailings per month WW II	Estimated Peak Cap. Sailing per Month	Control-ling Depth (feet)
BOSTON	500,000	363	34	50	60	40
NEW YORK	1,600,000	2,210	300	160	180	45
PHILADELPHIA	400,000	400	22	40	50	34
BALTIMORE	350,000	400	15	35	35	34
HAMPTON ROADS	550,000	525	28	55	60	40
CHARLESTON	110,000	146	8	11	16	34
NEW ORLEANS	600,000	1,000	33	60	75	37
LOS ANGELES	600,000	365	28	60	60	35
SAN FRANCISCO OAKLAND	1,000,000	1,200	98	100	120	40
SEATTLE	500,000	455	20	40	50	40
TOTAL	6,210,000	7,064	586	601	706	

TABLE II-2

MINOR U. S. PORTS
CAPACITY FOR WAR SHIPPING
(Current and after 12 months)

	Port	Estimated Maximum M/T That Could Be Shipped per Month Now	Estimated Maximum M/T That Could Be Shipped 12 Months Hence	Sustained Daily Rail Capacity 30 T Cars	Number Berths Actual	Number Berths Effective	Max. No. Sailing Per Month Now	Max. Berth Cap. 12 Months Hence	Maximum No. Sailings 12 Months Hence	Limiting Factor Rail Support or Berths
CANADA	Halifax	200,000	280,000	275	14	14	20	14	28	Berths
	St. John, N.B.	270,000	360,000	235	18	18	27	18	36	Berths
NORTH ATLANTIC										
NEW ENGLAND	Portland, Me.	180,000	260,000	245	13	10	18	13	26	Berths
	Searsport	40,000	40,000	140	2	2	4	2	4	Berths
	New Bedford	40,000	40,000	25	2	2	4	2	4	Berths
	Providence	40,000	90,000	50	6	2	4	6	9	Rail
	New London	40,000	80,000	90	4	2	4	4	8	Berths
	New Haven	20,000	40,000	25	3	1	2	2	4	Rail
	Bridgeport	40,000	40,000	25	2	2	4	2	4	Rail
	SUB-TOTAL	870,000	1,230,000	1110	64	53	87	63	123	
MIDDLE ATLANTIC	Albany, N.Y.	80,000	100,000	100	4	4	8	5	10	Berths
	Wilmington, Del.	80,000	80,000	60	4	4	8	4	8	Berths
	Chester, Pa.	20,000	80,000	60	4	1	2	4	8	Berths
	SUB-TOTAL	180,000	260,000	220	12	9	18	13	26	
SOUTH ATLANTIC	Wilmington, N.C.	40,000	90,000	55	8	2	4	5	9	Rail
	Charleston, S.C.	140,000	160,000	146	8	7	14	8	16	Berths
	Savannah, Ga.	320,000	400,000	231	28	16	32	28	40	Rail
	Jacksonville	240,000	360,000	205	23	12	24	18	36	Rail
	Port Everglades	80,000	120,000	116	10	4	8	10	12	Rail
	Miami	80,000	80,000		10	4	8	10	8	Rail
	SUB-TOTAL	900,000	1,210,000	753	87	45	90	79	121	

TABLE II-2 (cont.)

	Port	Estimated Maximum M/T That Could Be Shipped per Month Now	Estimated Maximum M/T That Could Be Shipped 12 Months Hence	Sustained Daily Rail Capacity 30 T Cars	Number Berths Actual	Number Berths Effective	Max. No. Sailing per Month Now	Max. Berth Cap. 12 Months Hence	Maximum No. Sailings 12 Months Hence	Limiting Factor Rail Support or Berths
GULF OF MEXICO	Tampa	120,000	130,000	77	10	6	12	7	13	Rail
	Panama City	40,000	60,000	35	3	2	4	3	6	Rail
	Pensacola	60,000	80,000	129	4	3	6	4	8	Berths
	Gulfport	60,000	80,000	69	4	3	6	4	8	Berths
	Mobile	360,000	460,000	257	24	18	36	30	46	Rail
	Port Arthur	90,000	90,000	50	8	5	9	5	9	Rail
	Galveston	580,000	580,000	325	42	30	58	42	58	Rail
	Houston	400,000	460,000	400	23	20	40	23	46	Berths
	Beaumont	80,000	90,000	50	6	4	8	5	9	Rail
	Corpus Christi	70,000	70,000	40	6	6	7	6	7	Rail
	Lake Charles, La.	70,000	70,000	40	6	6	7	6	7	Rail
	SUB-TOTAL	1,930,000	2,170,000	1472	136	103	193	135	217	
WEST COAST	Richmond	40,000	80,000	50	3	2	4	4	8	Berths
	Stockton	100,000	160,000	100	7	5	10	8	16	Berths
	Portland, Ore.	320,000	500,000	500	26	16	32	25	50	Berths
	Everett	60,000	60,000	-	3	3	6	3	6	Rail
	Tacoma	180,000	200,000	110	14	9	18	14	20	Rail
	Olympia	20,000	20,000	-	1	1	2	1	2	Berths
	Longview	40,000	140,000	-	7	2	4	7	14	Berths
	Astoria	140,000	220,000	125	12	7	14	12	22	Rail
	SUB-TOTAL	900,000	1,380,000	885	73	45	90	74	138	

TABLE II-3

COMPARISON MAJOR AND MINOR U. S. PORTS AS TO RELATIVE CAPACITY (by Coastal Region)

Major Port (POE) and Nearby Coastal Region	MAJOR PORTS: Max. WW II Utilization (by Month M/T)	MAJOR PORTS: Estimated Peak Capacity 12 Months Hence (by Month M/T)	NEARBY MINOR PORTS: Estimated Capacity Now M/T	NEARBY MINOR PORTS: Estimated Capacity 12 Months Hence Without Major Construction M/T	RELATIVE CAPACITIES (+) Minor Ports M/T Advantage Major Regional Port (-) Major Port Advantage: Now	RELATIVE CAPACITIES: 12 Months Hence	Suggested Diversions, Adjustments and Development to Provide Alternate Port Capacity in Lieu of Major Ports
			NORTH ATLANTIC REGION				
Boston	500,000	600,000	870,000	1,230,000	+370,000	+630,000	Plan to accept 370,000 M/T initially, and 630,000 M/T within 12 months from New York, a contiguous area.
			MIDDLE ATLANTIC REGION				
New York Philadelphia	1,600,000 400,000 2,000,000	1,800,000 500,000 2,300,000	180,000	260,000	-1,820,000	-2,040,000	Plan to divert freight originating in Buffalo and West and Pittsburgh and West through Gulf ports. Develop Delaware River ports to handle Philadelphia contiguous export, New York contiguous export via N. Atlantic minor ports. Provide for lighter operations on Hudson River and Delaware River.
			SOUTH ATLANTIC REGION				
Baltimore Hampton Roads Charleston	350,000 550,000 110,000 1,010,000	350,000 600,000 160,000 1,110,000	900,000	1,210,000	-110,000	-100,000	The minor ports of the South Atlantic region have sufficient port capacity. Dredging and rehabilitation work is required. Rail support limits development of ports in this region. No diversions or particular adjustment problem exists.
			GULF OF MEXICO REGION				
New Orleans	600,000	750,000	1,930,000	2,170,000	+1,330,000	+1,420,000	The minor ports of the Gulf can accept the New Orleans export plus the New York-Philadelphia export, originating in North Central and Central U. S. The Gulf could accept West Coast diversions without extensive new construction.
			WEST COASTAL REGION				
Los Angeles San Francisco Seattle	600,000 1,000,000 500,000 2,100,000	600,000 1,200,000 500,000 2,300,000	900,000	1,380,000	1,200,000	-920,000	The minor ports of the Pacific Coast provide approximately one-half the capacity of the major ports. Plans should be drawn for the handling of export cargo in greater quantity through minor ports of Puget Sound, Columbia River and San Francisco Bay.
TOTALS	6,210,000	7,060,000	4,780,000	6,250,000			

TABLE III-1

CAPACITY OF RAILROADS FOR HOLDING EXPORT FREIGHT IN CARS WITHOUT INTERFERING WITH CURRENT OPERATIONS(a)

(NORTH ATLANTIC PORTS)

Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles from Port
Searsport, Maine	BAR	398	15	Sandy Point	7
			46	Prospect	11
			33	Frankfort	16
			44	Winterport	20
			47	Arey	25
			8	Hampden	26
	TOTAL	398	193		
Portland, Maine	CN	350	0		
	PT	658	0		
	TOTAL	1008	0		
Boston, Mass.	B&A	781	0		
	B&M	1200			
	NH	1575	1050	Readville	10
			130	Mansfield	25
			130	Attleboro	32
	TOTAL	3556	1310(b)		
New Bedford, Mass.	NH	63	0		
Providence, R.I.	NH	500(b)	0		
New London, Conn.	NH	140	0		
	CV	225	0		
	TOTAL	365	0		
New York (includes Port Newark, N.J.)	B&O (SIRT)	750	0		
	CNJ-B&O	1400	0		
	DL&W	1500	500	Scranton	132
	ERIE	1325	0		
	H.M.	210	0		
	LV	1500	200	S. Plainfield	26
	NYC(WS)(O&W)	2941	0		
	NYC(Manhattan)	840	0		
	NH	300	400	Cedar Hill	70
	NYO&W	(see NYC)	71	Cornwall	52
			900	Middletown	79
			404	Cadosia	160
	PRR	3000	1226	W. Morrisville	56
	TOTAL	13766	3701		
Philadelphia	B&O	450	100	Wilsmere, Del.	29
			50	Twin Oaks, Pa.	33
	PRR	2600	0		
	RDG	2100	0		
	TOTAL	5150	150		

Table III-1 (NORTH ATLANTIC PORTS, Cont'd.)

Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles from Port
Camden, N.J.	PRR	50	0		
Baltimore, Md.	B&O	1500	350	Brunswick, Md.	72
	Canton	800	0		
	PRR	1500	0		
	WM	1140	60	Emory Grove, Md.	22
	TOTAL	4940	410		
Hampton Roads	ACL	282	0		
	C&O	5000	0		
	N&W	3700	0		
	NS	50	0		
	PRR	0	0		
	Seaboard	100	0		
	SOU	250	0		
	VGN	700	0		
	TOTAL	10082	0		
(SOUTH ATLANTIC & GULF PORTS)					
Wilmington, N.C.	ACL	250	0		
	SAL	172	0		
	TOTAL	422	0		
Charleston, S.C.	ACL	500	0		
	PUC	300	0		
	SAL	0	0		
	SOU	800	0		
	TOTAL	1600	0		
Savannah, Ga.	ACL	350	0		
	C of G (Inc. Sou.)	1137	0		
	SAL	225	0		
	S&A	50	0		
	TOTAL	1762	0		
Jacksonville, Fla.	ACL	600	0		
	FEC	0	0		
	MD&T	248	0		
	SAL	129	0		
	SOU	150	0		
	TOTAL	1127	0		
W. Palm Beach, Fla.	West Indies F&S Co.	200	(c)	Fort Pierce (FEC)	57
Port Everglades, Fla.	PE Belt Line	350	300(c)	Fort Pierce(FEC)	100
			60	Fort Lauderdale (SAL,	
	TOTAL	350	360		
Miami, Fla.	FEC	294	0		
	MD&T	0	0		
	SAL	50	0		
	TOTAL	344	0		

Table III-1	(SOUTH ATLANTIC GULF PORTS, (Cont'd.)				
Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles from Port
Tampa - Port Tampa Fla.	ACL	800	0		
	SAL	200	0		
	TOT L	1000	0		
Pensacola, Fla.	L&N	884	0		
	StL&SF	389	0		
	TOTAL	1273	0		
Mobile, Ala.	AT&N	150	30	Chickasaw	5
	GM&O	400	0		
	L&N	400	0		
	Tml.Ry. ASD	300	0		
	SOU	200	0		
	TOTAL	1450	30		
Theodore, Ala.	L&N	200	0	(d)	
Gulfport, Miss.	L&N	0	0		
	IC	343	0		
	TOTAL	343	0		
New Orleans, La.	GM&O	150	0		
	IC	1862	0		
	L&A	200	0		
	L&N	350	0		
	L.S.	115(d)	0		
	NOLC	365(d)	0		
	NOPB	600	0		
	SOU	500	150	Picayune, Miss.	47
	T&NO	52	0		
	TP-MP-Tml.	1275	0		
	TOTAL	5469	150		
Lake Charles, La.	T&NO	190	0		
	MP(Inc. KCS)	0	0		
	TOTAL	190	0		
Beaumont, Tex.	T&NO	145	0		
	MP	0	0		
	GC&SF	100	0		
	TOTAL	245	0		
Texas City, Tex.	TCT	500	0		
Houston, Tex.	BRI	0	110	Tomball	32
			150	Teague	151
	IGN	1120	0		
	PTRA	250	0		
	T&NO	280	0		
	MKT	200	0		
	HB&T	200	0		
	GC&SF	0	0		
	TOTAL	2050	260		

Table III-1 (SOUTH ATLANTIC & GULF PORTS, Cont'd.)

Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles From Port
Galveston, Tex.	BRI	400	0		
	GH&H	698	0		
	GW	840	0		
	GC&SF	900	473	(60 Texas City Jct.	11
				(72 Arcadia	20
				(110 Rosenberg	66
				(70 Sealy	95
				(100 Bellville	106
				(61 Beard	105
	T&NO	150	0		
	TOTAL	2988	473		
Corpus Christi, Tex.	CCT	0	0		
	T&NO	0	0		
	StLB M	0	0		
	T-M	150	0		
	TOTAL	150	0		
Brownsville, Tex.	StLB&M	0	300	Brownsville Yard	10
	T&NO	0	0		
	Brownsville Nav. Dist.	175	0		
	TOTAL	175	300		
(PACIFIC COAST PORTS)					
San Diego, Calif.	AT&SF	190	60	National City	5.6
	SD&AE	70	0		
	TOTAL	260	60		
Los Angeles, Calif. port area, inc. Long Beach.	AT&SF	450	0		
	H.B.	1000	0		
	S.P.	350	0		
	P.E.(e)	1225	0		
	U.P.	950	0		
	TOTAL	3975	0		
San Francisco Bay Area					
ATSF W.Bay Dist.		90	0		
E.Bay Dist.		594	0		
TOTAL AT&SF		684	0		
SP W. Bay Dist.		990	0		
E. Bay Dist.		600	0		
TOTAL SP		1590	0		
WP W. Bay Dist.		31	0		
E. Bay Dist.		651	0		
TOTAL WP		682	0		
State Belt W. Bay Dist.		580	0		

Table III-1 (PACIFIC COAST PORTS, Cont'd.)

Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles From Port
Alameda Belt E. Bay Dist.		200	0		
TOTAL SAN FRANCISCO BAY AREA		3736	0		
Stockton, Calif.	AT&SF	121	468	Riverbank	25
	SP	0			
	WP	250			
	TOTAL	371	468		
Portland Ore. Area (All Columbia River Ports)					
Kalama. Wash. (Joint GN-NP-UP)		30	0		
North Pac. Tml., Portland		450	0		
Peninsula Terminal, Portland		40	0		
SP, Portland		192	0		
SP&S, Portland		50	100	E. St. Johns	2
SP&S, Vancouver		50	0		
LP&N, Longview		0	0		
UP, Portland		300	270	Hemlock 50)	16
				Wyeth 100)	50
				Celilo 50)	97
				Dune 70)	92
TOTAL - Portland and Vicinity		1112	370		

(PUGET SOUND AREA)

Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles From Port
Aberdeen, Wash.	NP only	0	75	Aberdeen Jct.	3
	Joint NP-UP-CMStP&P	100			
	TOTAL	100	75		
Anacortes, Wash.	GN	5	0		
Bellingham, Wash.	CMStP&P	0	0		
	GN	25	0		
	NP	15	0		
	TOTAL	40	0		
Everett, Wash.	CMStP&P	0	0		
	GN	50	350	Goldbar (Avail. also for Seattle frt.)	28
	NP	30	0		
	TOTAL	80	350		
Olympia, Wash.	NP	65	30	Lacey	5
			28	Belmore	5.3
	UP	50	0		
	TOTAL	115	58		

TABLE III-1 (PUGET SOUND AREA, Cont'd.)

Port	Road	Within Port Area Cars	Outside Port Area Cars	Holding Point	Miles From Port
Seattle, Wash.	CMStP&P	200	95	Black River (Avail. also for Tacoma frt.)	9
	GN	300	350	Goldbar (Avail. also for Everett frt.)	60
			150	Richmond Beach	8
	NP	500	102	Auburn(Avail.also for Tacoma frt.)	
	PC	85	0		
	UP	150	0		
	TOTAL	1235	697		
Tacoma, Wash.	CMStP&P	150	95	Black River(Avail. also for Seattle frt.)	28
	GN	133	0		
	NP	225	102	Auburn(Avail.also for Seattle frt.)	18
	UP	50	0		
	TOTAL	558	197		

(a) ASSOCIATION OF AMERICAN RAILROADS - Office of Manager of Port Traffic.
(b) The 500 car capacity at Providence can be used to hold Boston export if needed.
(c) The 300 car capacity can be used to hold W. Palm Beach export if needed.
(d) Explosives only.
(e) Includes Municipal Ry. trackage Long Beach, worked by PE.

TABLE V-1

PORT TIME BREAKDOWN FOR NAVY-OPERATED VESSELS (June 1943)

Dry Cargo Vessels	New York	San Francisco	Puget Sound	Tampa	Norfolk	Portland, Ore.	Boston	Portland, Me.	Baltimore, Md.	Hueneme, Cal.	San Diego, Cal.
No. vessels cleared	548	215	139	90	160	86	43	47	52	19	15
Dry Cargo Vessels Working Cargo	286	181	100	45	44	43	43	41	39	18	15
Total Days Loading and Discharging	3185	1779	574	188	354	502	393	234	386	90	32
Avg. days working	11.0	9.8	5.7	4.2	8.0	11.7	9.1	5.7	9.8	5.0	2.1
Awaiting Shifting at Berth	3	8	57	--	56	--	--	50	--	--	--
Awaiting Convoy	79	10	3	34	61	--	--	--	--	--	--
Awaiting Orders	50	--	3	--	11	--	--	--	--	--	--
Awaiting Cargo	--	--	50	--	2	3	--	1	--	--	--
Acct. of Stevedores	--	--	45	--	--	100	--	3	--	--	--
" " Crew	--	--	--	--	--	1	--	--	--	--	--
Bunkers and Stevedores	--	16.0	30	--	7	15	3	--	--	--	--
Deperming	2	51	--	--	10	9	--	--	--	--	--
Idle other causes	9	30	49	--	--	2	231	9	--	--	--
Total days working and delayed	3301	1894	811	222	501	632	627	297	386	90	32
Avg. days working and delayed	11.5	10.5	8.1	4.9	11.4	14.7	14.6	7.2	9.6	5.0	2.1
Days converting and repairing	2080	1368	590	28.0	155	218	47	13	502	--	--
Total days in Ports	5381	3262	1401	250	656	850	674	310	888	90	32
Avg. " " "	18.8	18.0	14.0	5.6	14.9	19.7	15.7	7.6	22.8	5.0	2.1

Table V-2

PORT TIME BREAKDOWN FOR ARMY-OPERATED VESSELS

AVERAGE TIME PER SHIP (1st Quarter 1945)

Time in Port	All Ports	Boston	New York	Hampton Roads	Charleston	New Orleans	Los Angeles	San Francisco	Seattle
Total Days	17.2	12.8	17.3	15.1	10.2	14.1	15.9	25.[illegible]	21.5
Army Days	10.5	9.7	9.5	10.4	6.1	7.7	9.4	13.5	13.1
Days Available for Loading	7.2	8.6	7.5	5.9	5.3	6.2	7.7	8.8	6.0
Army Hours Lost	71.6	25.9	48.5	108.4	19.9	36.3	15.6	114.4	168.2
Waiting Convoy	14.2	0	20.8	29.4	0	0	0	0	0
Repairs	11.3	1.3	1.9	4.0	1.3	1.2	4.7	46.8	64.5
Waiting Labor	5.9	3.0	2.3	10.2	0.6	0	5.5	0.2	27.1
Waiting Cargo	8.5	3.9	5.1	19.9	5.6	1.2	0	4.4	18.4
Bad Weather	5.7	7.9	4.2	12.3	5.0	5.3	1.8	0.7	1.6
Discharging	1.4	0.7	0.3	1.6	4.3	0	0	0.5	11.3
Waiting Berth	2.2	0.5	0.2	10.0	0	0	0	0	0.4
Shifting Berth	2.5	2.6	0.5	0.2	0.1	22.5	0.7	2.4	8.6
Other Delays	19.9	6.0	13.2	20.8	3.0	6.1	2.9	60.0	36.3
Number of Ships	1,384	173	524	276	39	60	84	112	116

Source - Page 43 Monthly Progress Report Ser. 3 - Transportation Corps.

TABLE V-3		
U.S. OWNED OR CONTROLLED COMMERCIAL-TYPE DRY CARGO VESSELS		
Speed Range	No. Ships	Dead Weight Tons
Over 16 knots	365	3,660,000
14 to 15.9 knots	500	4,790,000
12 to 13.9 knots	35	188,000
Under 12 knots	1,927	20,102,000
Total	2,827	28,740,000

TABLE V-4

TONS LOADED PER DAY PER VESSEL

Ports of Embarkation	Number of Ships	First Half 1945: Tons Loaded Per Ship				
		Tons Loaded Per Ship L/T	Tons Loaded Per Ship M/T	Days Available for Loading Per Ship	Tons Loaded Per Day Per Ship L/T	Tons Loaded Per Day Per Ship M/T
Boston	291	4,900	8,700	9	500	1,000
New York	567	4,500	8,800	8	600	1,100
Philadelphia	216	5,000	7,900	4	1,300	2,000
Baltimore	192	5,500	9,100	5	1,100	1,800
Hampton Roads	293	5,500	9,000	5	1,100	1,800
Charleston	69	5,900	8,900	5	1,200	1,800
New Orleans	175	6,200	9,500	7	900	1,400
Los Angeles	186	5,300	11,100	7	800	1,600
San Francisco	293	5,300	10,700	8	700	1,300
Portland, Ore.	46	6,200	9,600	9	700	1,100
Seattle	195	4,100	9,000	6	700	1,500
Prince Rupert	21	3,200	4,900	4	800	1,200
ALL PORTS	2,544	5,100	9,200	7	700	1,300

Source: Sec. 3 Progress Report, - 3 July 1945

TABLE V-5

DISCHARGE RATES FOR 11 REPRESENTATIVE OVERSEAS PORTS
(February-July, 1945)

Overseas Ports of Debarkation	Number of Ships	Tons Discharged Per Ship		Net Days Discharging	Tons Discharged	
		L/T	M/T		Per Day L/T	Per Ship M/T
Antwerp	521	5,100	8,950	5.5	921	1,616
Bremerhaven	26	6,500	9,790	5.7	1,147	1,733
Ghent	56	5,000	6,800	5.6	907	1,225
Genoa	9	7,500	8,980	4.4	1 695	2,022
Cherbourg	134	4,940	6,630	7.4	629	899
Casa Blanca	17	3,730	7,250	4.0	932	1,810
Calcutta	149	4,750	11,050	3.7	1,275	2,964
Beak I D	20	2,320	9,230	6.2	374	1,488
Honolulu	112	4,280	9,000	5.6	762	1,616
Liverpool	44	2,460	8,800	4.2	582	2,079
Marseilles	341	4,320	7,950	5.5	591	1,457
ALL PORTS	1,429	4,711	8,627	5.5	877	1,655

TABLE VI-1

EXPERIMENTAL LOADING OF 3 LST'S

Item	(1) Conventional Operation	(2) 50 Per Cent Unitized	(3) 100 Per Cent Work-Managed
Per cent unitized	13	65	94
Weight tonnage (2240#)	741	937	914.5
No. of unit loads	50*	476*	698*
Hatch-hours	62-1/2	31-1/2	27-1/4
Man-hours	922	693	288
Long tons/hatch-hour	12	29.5	33.5
Long tons/man-hour	0.8	1.35	3.16
Cost/ton	$1.25	$0.74	$0.30

*P.T. Motor considered one unit load

TABLE VI-2

GENERAL CARGO VESSEL CARGO-HANDLING RATES AND PRESENT AND PROBABLE OPTIMUM U. S. PORT TIME

Item	Existing Port Terminals Conventional Methods		Selected Work-Managed and Mechanized Terminals	
	Existing Ships (Liberty) (11-knot)	New Fast Ships (20-knot)	Existing Ships	New Fast Ships
Long tons/man-hour Long tons/hatch/hour	0.8 12.0	1.6 20.0	1.2 20.0	2.5 40.0
Days loading ship	4.5	3.0	3.0	2.0
Non effective port time with convoy	10.0	7.5	10.0	7.5
Non effective port time without convoy	2.5	2.5	2.5	2.5
Expected time spent in U.S. ports with convoy	15.0	10.5	13.0	9.0
Expected time in U.S. ports without convoy	7.0	5.5	5.5	4.5
Number of ships required to supply 10^6 troops N.Y. to Liverpool, cont. convoy	236*	132	1[illegible]4	124
Number of ships required to supply 10^6 troops N.Y. to Liverpool without convoy	206*	93	136	84

* Based on actual performance

GROUP "A": Ports having estimated trans-shipment capacity of 100 or more carloads per day.

ANNEX A

ESTIMATED CAPACITY FOR HANDLING GENERAL CARGO AT PRINCIPAL U. S. PORTS
(Not Including Bulk Grain, Bulk Petroleum Products or Coal)
AS OF OCTOBER 1, 1949

		TRANS-SHIPMENT CAPACITY (With Full Manpower)					R.R. STORAGE CAPACITY			HOLDING CAPACITY FREIGHT IN CARS WITHOUT INTERFERING WITH CURRENT OPERATIONS		
					Peak Unloading Recorded							
NORTH ATLANTIC PORTS	Serving R.R.'s	Max. Trans-Shipment Cap. C/L (1)	Import Plus Coastwise Use C/L (2)	Net Export Cap. C/L (1)(2)(3)	Avg. Daily Unloading C/L (4)	Week Ending (5)	Covered Piers C/L's (6)	Open Piers and Ground C/L (7)	Total C/L's (8)	Within Port Area (9)	Outside Port Area (10)	Total (11)
Searsport, Maine	BAR	140	0	140	120	3/25/48	107	102	209	398	193	591
Portland, Maine	PT-CN-BandM-MEC	445	200	245	107	3/28/47	425	235	660	1,008	0	1,008
Boston, Mass.	BandM-NH-NYC Sys	513	150	363	347	3/17/45	0	1,860	1,860	3,556	1,310	4,866
NY Harbor (Inc. Pt. Newark)	(a)	2,470	260	2,210	1,925	5/6/44	5,391	11,577	16,968	13,766	3,701	17,467
Philadelphia, Pa.	BandO-PRR-RDG	500	100	400	485	3/31/45	0	2,458	2,458	5,150	150	5,300
Baltimore, Md.	BandO-PRR-WM (Canton)	500	100	400	439	3/17/45	1,170	2,858	4,028	4,940	410	5,350
Hampton Roads, Va.	(b)	850	325	525	600	3/31/45	2,020	3,830	5,850	10,082	0	10,082
TOTAL		5,418	1,135	4,283	4,023		9,113	22,920	32,033	38,900	5,764	44,664
SOUTH ATLANTIC AND GULF PORTS												
Wilmington, N. C.	ACL-SAL	111	56	55	30	9/10/46	0	580	580	422	0	422
Charleston, S. C.	ACL-SAL-SOU	180	34	146	115	1/20/45	250	50	300	1,600	0	1,600
Savannah, Ga.	ACL-CGA-SAL-SOU-SandA	304	73	231	107	8/24/45	1,766	2,425	4,191	1,762	0	1,762
Jacksonville, Fla.	ACL-FEC-JT-SAL-SOU	321	116	205	60	7/17/45	1,020	1,480	2,500	1,127	0	1,127

GROUP "A": Ports having estimated trans-shipment capacity of 100 or more carloads per day.

ANNEX A (cont.)

ESTIMATED CAPACITY FOR HANDLING GENERAL CARGO AT PRINCIPAL U. S. PORTS
(Not Including Bulk Grain, Bulk Petroleum Products or Coal)
AS OF OCTOBER 1, 1949

		TRANS-SHIPMENT CAPACITY (With Full Manpower)					R.R. STORAGE CAPACITY			HOLDING CAPACITY FREIGHT IN CARS WITHOUT INTERFERING WITH CURRENT OPERATIONS		
					Peak Unloading Recorded							
SOUTH ATLANTIC AND GULF PORTS	Serving R.R.'s	Max. Trans-Shipment Cap. C/L (1)	Import Plus Coastwise Use C/L (2)	Net Export Cap. C/L (1)(2)(3)	Avg. Daily Unloading C/L (4)	Week Ending (5)	Covered Piers C/L's (6)	Open Piers and Ground C/L (7)	Total C/L's (8)	Within Port Area (9)	Outside Port Area (10)	Total (11)
Miami, Palm Beach Pt. Everglades	FEC-SAL	204	88	116	29	Mo.5/44	435	450	885	894	360	1,254
Tampa, Pt. Tampa	ACL-SAL	111	34	77	108	8/7/45	0	40	40	1,000	0	1,000
Pensacola, Fla.	LandN-SLSF	240	111	129	24	7/1/45	380	900	1,280	1,273	0	1,273
Theodore, Ala. (Explosives only)	LandN	100	0	100	68	10/10/47	0	0	0	350	0	350
Mobile, Ala.	LandN-ATandN-GMandO-SOU-ASD	300	43	257	141	8/4/45	797	1,650	2,447	1,450	30	1,480
Gulfport, Miss.	LandN-IC	103	34	69	50	8/6/45	0	0	0	343	0	343
New Orleans, La.	(c)	1,450	450	1,000	442	6/9/45	1,502	1,975	3,477	5,469	150	5,619
Houston, Tex.	BRI-GHandH-HBandT-MKT-MP-GCSF-TNO	400	135	265	186	6/20/47	0	0	0	2,050	260	2,310
Galveston, Tex.	BRI-GHandH-MKT-MP-GCSF-TNO-GW	325	50	275	219	5/29/47	0	4,277	4,277	2,988	473	3,461
TOTAL		4,149	1,224	2,925	1,579		6,150	13,827	19,977	20,728	1,273	22,001

(a) Railroads serving NY Harbor: BandO-CNJ-DLandW-ERIE-LV-NYC-NH-NYOW-NYSW-PRR-Terminal Switching Roads (Bedt, NY Dock, Jay St., Conn., Bush Term., Hoboken Shore)

(b) Railroads serving Hampton Roads: ACL-CandO-NandPBL-NS-NandW-SOU-SAL-VGN-PRR

(c) Railroads serving New Orleans: GMandO-IC-LandA-LandN-LS-MP-GCL-NOLC-TNO-TandP-TP-MP-Term.

GROUP "A": Ports having estimated trans-shipment capacity of 100 or more carloads per day.

ANNEX A (cont.)

ESTIMATED CAPACITY FOR HANDLING GENERAL CARGO AT PRINCIPAL U. S. PORTS (Cont'd)
(Not Including Bulk Grain, Bulk Petroleum Products or Coal)
AS OF OCTOBER 1, 1949

		TRANS-SHIPMENT CAPACITY (With Full Manpower)					R.R. STORAGE CAPACITY			HOLDING CAPACITY FREIGHT IN CARS WITHOUT INTERFERING WITH CURRENT OPERATIONS		
					Peak Unloading Recorded							
PACIFIC COAST PORTS	Serving R.R.'s	Max. Trans-Shipment Cap. C/L (1)	Import Plus Coastwise Use C/L (2)	Net Export Cap. C/L (1)(2)(3)	Avg. Daily Unloading C/L (4)	Week Ending (5)	Covered Piers C/L's (6)	Open Piers and Ground C/L (7)	Total C/L's (8)	Within Port Area (9)	Outside Port Area (10)	Total (11)
San Diego	ATSF-SDandAE	35	0	35	49	Mo.1/44	0	0	0	260	60	320
Los Angeles Harbor (Inc. Long Beach)	ATSF-LAJ-PE-SP	440	75	365	335	6/5/45	0	0	0	3,975	0	3,975
Port Hueneme (navy)	VCTY	255	0	255	255	Mo.5/45	0	0	0	1,000	250	1,250
San Francisco Bay Area	ATSF-NWP-PandSR-SN-SP-WP	1,275	75	1,200	1,081	5/26/45	0	0	0	3,736	0	3,736
Stockton	ATSF-SP-STandT-CCT-TS-WP	100	0	100	106	Mo.4/44	0	0	0	371	468	839
TOTAL CALIFORNIA PORTS		2,105	150	1,955	1,826		0	0	0	9,342	778	10,120
Portland, Ore. and Columbia River Ports	(d)	500	0	500	316	5/10/45	0	0	0	1,112	370	1,482
Seattle, Wash.	MILW-GN-NP-PC-UP	480	25	455	350	1/10/45	0	0	0	1 235	697	1,932
Tacoma and Olympia, Wash.	MILW-GN-NP-UP	160	50	110	90	5/31/45	0	0	0	673	255	928
Other Puget Sound Ports	(e)	125	0	125	--	--	0	0	0	225	425	650
TOTAL WASHINGTON AND OREGON PORTS		1,265	75	1,190	756		0	0	0	3,245	1,747	4,992

(d) Includes: Astoria (SPS); Marshland (SPS); Prescott (SPS); and St. Helens (SPS), Oregon. Kalama (GN-NP-UP); Longview (MILW-GN-LPN-NP-UP); and Van Couver (GN-NP-SPS-UP), Washington.

(e) Includes: Aberdeen (MILW-UP-NP)
Anacortes (GN)
Bellingham (GN-MILW-NP)
Hoquiam (MILW-NP-UP)
Port Angeles (MILW-PTAW)

GROUP "B": Ports having estimated trans-shipment capacity of less than 100 carloads per day.

ANNEX A (cont.)

ESTIMATED CAPACITY FOR HANDLING GENERAL CARGO AT PRINCIPAL U. S. PORTS
(Not Including Bulk Grain, Bulk Petroleum Products or Coal)
AS OF OCTOBER 1, 1949

		TRANS-SHIPMENT CAPACITY			R.R. STORAGE CAPACITY			HOLDING CAPACITY FREIGHT IN CARS WITHOUT INTERFERING WITH CURRENT OPERATIONS		
NORTH ATLANTIC PORTS	Serving R.R.'s	Max.Daily Unloadings C/L's (1)	Peak Unloading Total cars (2)	Recorded In Month (3)	Covered Piers C/L's (4)	Open Piers and Ground C/L's (5)	Total C/L's (6)	Within Port Area (7)	Outside Port Area (10)	Total (11)
New Bedford, Mass.	NH	25	--	(a)	0	0	0	63	0	63
Providence, R.I.	NH	50	55	11/44	0	114	114	500*	0	500*
Portsmouth, R.I.	NH	25	--	(a)	0	0	0	*	0	*
Davisville, R.I.(Navy)	NH	50	790	3/44	0	0	0	0	0	0
New London, Conn.	NH-CV	90	87	3/46	100	350	450	365	0	365
New Haven, Conn.	NH	25	140	3/44	0	50	50	250	0	250
Bridgeport, Conn.	NH	25	114	3/44	0	0	0	0	0	0
Poughkeepsie, N.Y.	NYC-NH	10	129	4/44	0	0	0	75	0	75
Albany, N.Y. (Note 8)	NYC-D&H-APD	10	--	(a)	0	0	0	300	0	300
Wilmington, Del.	B&O-PRR-RDG	60	--	(a)	40	60	100	200	330	530
TOTAL		370			140	574	714	1,753	330	2,083
SOUTH ATLANTIC GULF PORTS										
West Point, Va.(Note 1)	SOU	--	--	(a)	0	0	0	(a)	--	--
Morehead City, N.C. (Note 1)	A&EC	--	--	(a)	0	0	0	(a)	--	--
Brunswick, Ga.(Note 1)	ACL-SOU	--	--	(a)	0	0	0	(a)	--	--
Ft.Pierce, Fla. (Notes 1&2)	FEC	--	--	(a)	0	0	0	(a)	--	--
Fernandina, Fla.(Note 3)	SAL	10	203	11/45	0	0	0	(a)	--	--
Pt.St.Joe, Fla.(Note 4)	AN	25	--	(a)	0	100	100	250	0	250
Panama City, Fla. (Note 5)	A&StAB	30	1,783	10/47	0	187	187	95	1,828	1,923
S.Boca Gr., Fla. (Notes 1&6)	SAL	--	--	(a)	0	0	0	(a)	--	--
Pascagoula, Miss. (Note 1)	L&N-ME	--	--	(a)	0	0	0	(a)	--	--
Braithwaite, La.(Note 6)	LS	75	433	3/49	0	0	0	115	0	115
Lake Charles, La.	KCS-MP-TNO	40	450	7/45	0	0	0	190	0	190
Beaumont, Orange& Pt.Ar.Tex.	GSCF-KCS-MP-TNO	50	900	7/45	0	0	0	245	0	245
Texas City, Tex.(Note 7)	TCT	25	183	7/45	0	750	750	500	0	500
Corpus Christi, Tex.	CCT-MP-TNO-TM	40	58	5/44	0	0	0	150	0	150
Brownsville, Tex.	BND-MP-TNO	50	394	8/49	80	40	120	70	208	278
TOTAL		345			80	1,077	1,157	1,615	2,036	3,651

(a) No record available. * Also available for Boston and Portsmouth holdings.

Note 1: No facilities for hauling export or import general cargo in quantity.

Note 2: Ft. Pierce, Fla., has privately owned small wharf on which is located a cooling plant.

Note 3: Fernandina has a small wharf suitable for handling phosphate rock.

Note 4: Pt.St.Joe has 1 wharf 100' x 300' used by tankers for unloading cased petroleum products.

Note 5: Facilities owned by Int. Paper Co.

Note 6: Phosphate ore explosives only.

Note 7: Not including freight in cars via seatrain.

Note 8: Grain only, handled in recent years - general cargo facilities having been leased to government.

ANNEX A

ESTIMATED "THROUGH-PUT" CAPACITY U. S. PORTS (EACH 24 HOURS)

GRAIN

NORTH ATLANTIC PORTS: GROUP A	General Cargo Short Tons (Note 1)	(000) Bushels Elevator to Ships (Note 2)	Cars to Elevator (Note 3)	Coal Gross Tons (000)
Searsport, Me.	3,500	0	-	0
Portland, Me.	11,125	336	260	0
Boston, Mass.	12,825	448	300	0
NY Harbor (Inc. Pt. Newark)	61,750	826	540	736
Philadelphia	12,500	1,400	880	35
Baltimore, Md.	12,500	2,100	1,320	88
Hampton Roads, Va.	21,250	268	280	160
TOTAL (A)	135,450	5,378	3,580	419
GROUP B (Smaller Ports)				
New Bedford, Mass.	625	0	0	0
Providence, R. I.	1,250	0	0	0
Portsmouth, R. I.	625	0	0	0
Davisville, R. I. (Navy)	1,250	0	0	0
New London, Conn.	2,250	0	0	0
New Haven, Conn.	625	0	0	0
Bridgeport, Conn.	625	0	0	0
Poughkeepsie, N. Y.	250	0	0	0
Albany, N. Y.	250	1,400	400	0
Wilmington, Del.	1,500	0	0	0
TOTAL (B)	9,250	1,400	400	0
TOTAL	144,700	6,778	3,980	419

ANNEX A (cont.)

GRAIN

SOUTH ATLANTIC AND GULF PORTS: GROUP A	General Cargo Short Tons (Note 1)	(000) Bushels Elevator to Ships (Note 2)	Cars to Elevator (Note 3)	Coal Gross Tons (000)
Wilmington, N. C.	2,775	0	0	18
Charleston, S. C.	4,500	0	0	*
Savannah, Ga.	7,600	0	0	0
Jacksonville, Fla.	8,000	0	0	0
Miami, Pt. Everglades, Palm Beach	5,000	0	0	0
Tampa, Pt. Tampa, Fla.	2,775	0	0	0
Pensacola, Fla.	6,000	0	0	14
Theodore, Ala. (Explosives only)	2,500	0	0	0
Mobile, Ala.	7,500	0	0	14
Gulfport, Miss.	2,600	0	0	0
New Orleans, La.	36,250	420	600	7
Houston, Tex.	10,000	1,400	480	*
Galveston, Tex.	8,100	1,400	900	*
TOTAL (A)	103,600	3,620	1,980	53
GROUP B (Smaller Ports)				
Fernandina, Fla.	250	0	0	0
Port St. Joe, Fla.	625	0	0	0
Panama City, Fla.	750	0	0	0
Braithwaite, La.	1,875	0	0	0
Lake Charles, La.	1,000	0	0	0
Beaumont, Orange and Pt. Arthur, Tex.	1,250	280	(Pt.A)180	(Pt.A)7
Texas City, Tex.	625	0	0	0
Corpus Christi, Tex.	1,000	0	0	0

ANNEX A (cont.)

GRAIN

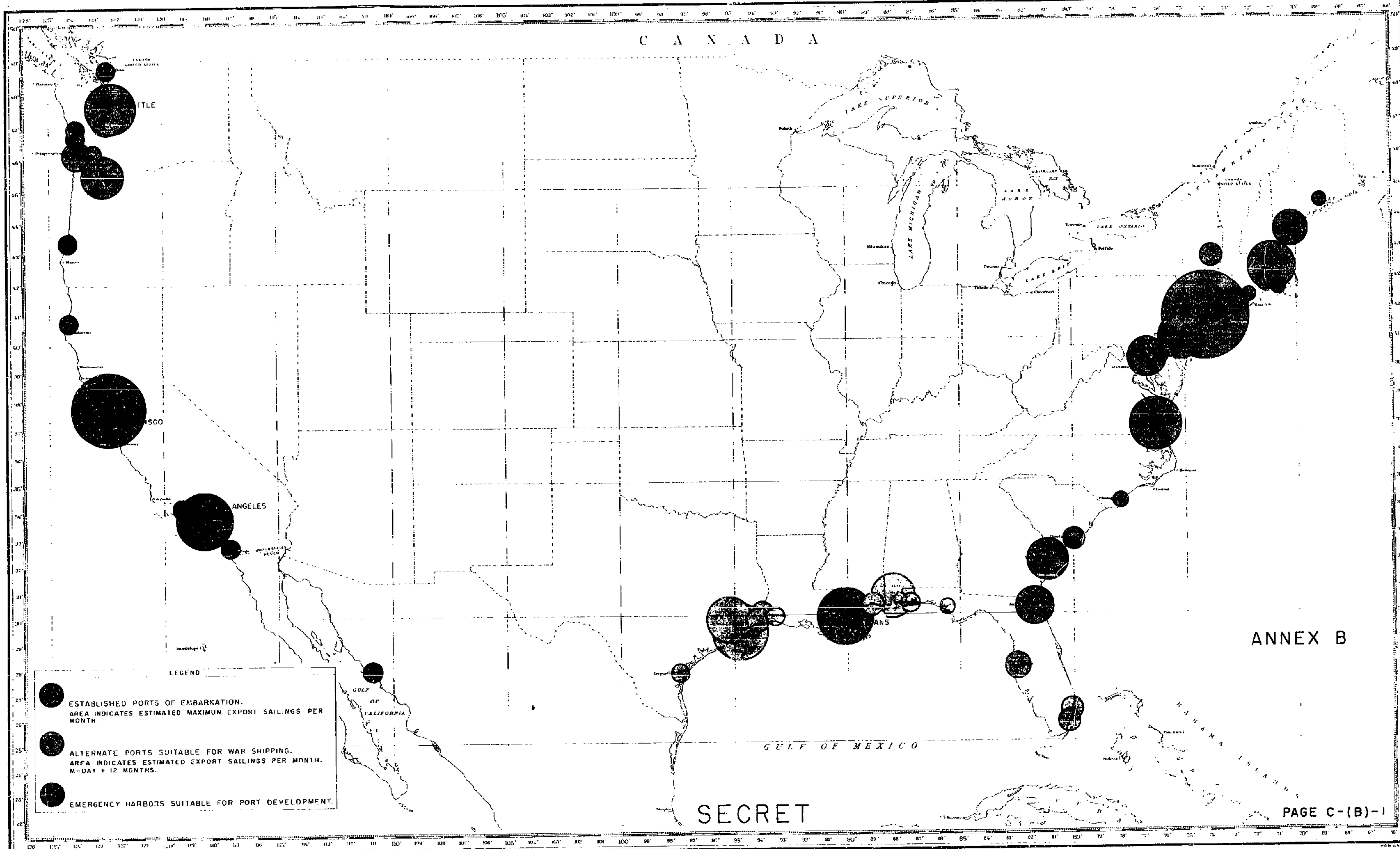
SOUTH ATLANTIC AND GULF PORTS: GROUP B (Cont.)	General Cargo Short Tons (Note 1)	(000) Bushels Elevator to Ships (Note 2)	Cars to Elevator (Note 3)	Coal Gross Tons (000)
Brownsville, Tex.	1,250	0	0	0
TOTAL (B)	8,625	280	180	7
TOTAL	112,225	3,900	2,160	60
PACIFIC COAST PORTS:				
San Diego, Calif.	875	84	-	1
Los Angeles Harbor (Inc. L.B. and S.Pedro)	11,000	77	-	6
Port Hueneme, Calif. (Navy)	6,400			0
San Francisco Bay Area	31,900	371	180	0
Stockton, Calif.	2,500	0	0	0
Portland, Ore. and Columbia River Ports	12,500	889	920	4
Seattle, Wash.	12,000	210	160	5
Tacoma and Olympia, Wash.	4,000	140	300	0
Other Puget Sound Ports	3,125	0	0	0
TOTAL	84,300	1,771	1,560	16
GRAND TOTAL all U. S. Ports	341,225	12,449	7,700	495

* Emergency only. By clam shell

Note 1 - Represents Max. Transshipment Capacity in Carloads Estimated at 25 Tons per car

Note 2 - Represents Hourly Capacity for Delivery to Ships Multiplied by 14 Hours out of each 24

Note 3 - Represents Hourly Capacity for Unloading to Elevator Multiplied by 20 Hours out of each 24


CANADA
LAKE SUPERIOR
LAKE MICHIGAN
LAKE HURON
LAKE ONTARIO
LAKE ERIE
GULF OF MEXICO
GULF OF CALIFORNIA
BAHAMA ISLANDS
TTLE
SCO
ANGELES
ANS
LEGEND
ESTABLISHED PORTS OF EMBARKATION.
AREA INDICATES ESTIMATED MAXIMUM EXPORT SAILINGS PER MONTH.
ALTERNATE PORTS SUITABLE FOR WAR SHIPPING.
AREA INDICATES ESTIMATED EXPORT SAILINGS PER MONTH. M-DAY + 12 MONTHS.
EMERGENCY HARBORS SUITABLE FOR PORT DEVELOPMENT.
ANNEX B

SECRET

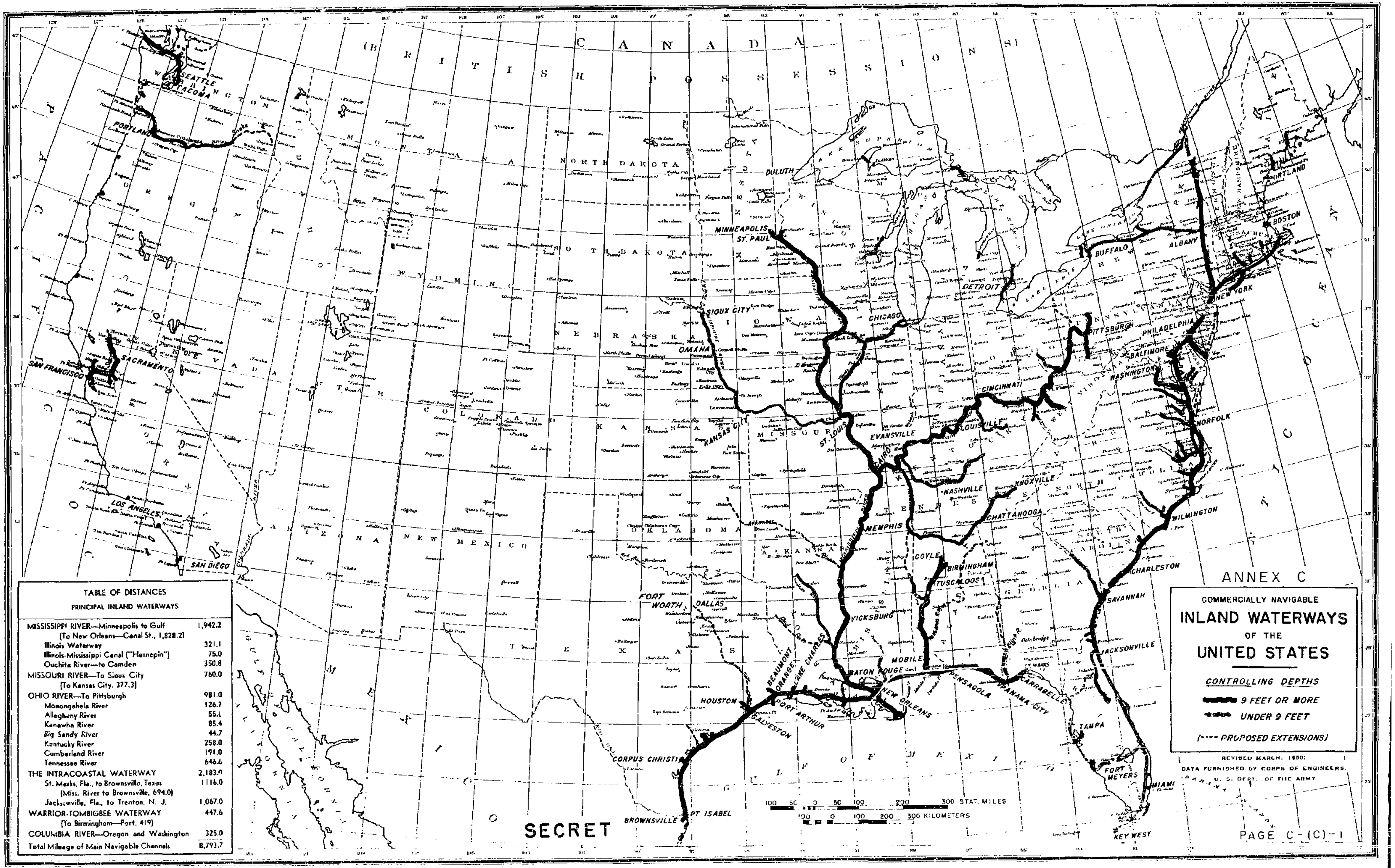


TABLE OF DISTANCES

PRINCIPAL INLAND WATERWAYS

MISSISSIPPI RIVER—Minneapolis to Gulf		1,942.2
(To New Orleans—Canal St., 1,828.2)		
Illinois Waterway	321.1	
Illinois-Mississippi Canal ("Hennepin")	75.0	
Ouchita River—to Camden	350.8	
MISSOURI RIVER—To Sioux City	760.0	
(To Kansas City, 377.3)		
OHIO RIVER—To Pittsburgh	981.0	
Monongahela River	126.7	
Allegheny River	55.L	
Kanawha River	85.4	
Big Sandy River	44.7	
Kentucky River	258.0	
Cumberland River	191.0	
Tennessee River	646.6	
THE INTRACOASTAL WATERWAY	2,183.0	
St. Marks, Fla., to Brownsville, Texas	1116.0	
(Miss. River to Brownsville, 694.0)		
Jacksonville, Fla., to Trenton, N. J.		1,067.0
WARRIOR-TOMBIGBEE WATERWAY		447.6
(To Birmingham—Port. 419)		
COLUMBIA RIVER—Oregon and Washington		325.0
Total Mileage of Main Navigable Channels		8,793.7

SECRET

ANNEX D

INVENTORY U.S. OWNED OR CONTROLLED DRY CARGO VESSELS (1950)*

Vessel Types	Number	Deadweight (tons)	Sea Speed (knots)
Total Fast	365	3,660,000	over 16
Victory VC2-S-AP3	96		17
C2-SU	6		16
C2-S-A1	2		16 1/2
C3	141		16 1/2
C4	37		17
Not Classified	83		16 to 20
Total Intermediate Fast	500	4,790,000	14 to 15.9
C1-A (B etc.)	94		14
C2	200		15 1/2
Victory VC2-S-AP2	177		15 1/2
Not Classified	29		14 to 15.9
Total Medium Slow	35	188,000	12 to 13.9
Total Slow	1927	20,102,000	Under 12
Liberty EC2	1775		11
C1	98		10 to 11
Not Classified	54		to 12
Grand Total	2827	28,740,000	

*U.S. Maritime Administration Reports #190 of June 30, 1950; March 31, 1950.

APPENDIX E

HARBOR DEFENSE

(Note: This Appendix should be read in conjunction with Appendix F, Mines and Mine Countermeasures)

I. INTRODUCTION

The present survey is not an exhaustive examination of our present harbor-defense system, but, rather, is intended to emphasize the most important needs of such a system.

The primary function of harbor defense is to provide a safe haven for ships in time of war. This must include safety from air, surface, or subsurface attack that employs either conventional explosives or atomic weapons. All harbors need not be defended against all weapons, of course, for many are endangered by only a few threats, either because of great distances from enemy bases or because of other factors. However, an effective harbor defense is prepared to counter any contingency by utilizing any or every measure and countermeasure (and any combination of these) in all important harbors at both ends of the supply routes.

Harbor defense is not primarily a matter of research and development. It is, instead, a matter of fusing diverse organizations -- Navy, Coast Guard, Corps of Engineers, local port authorities, and others -- into a homogenous working structure, and of adapting existing devices from many fields -- sonar, radar, AA, mine warfare, oceanography -- into a coordinated yet flexible system. Again, these concepts must apply equally at the destination ends of our overseas supply routes.

In peacetime, the various port and harbor-defense functions are the responsibilities of several agencies. This heterogeneity of organizations in peacetime makes difficult an over-all plan for harbor defense, for division of responsibility, and for coordination of separate functions. Yet the Navy, which has the responsibility of harbor defense in time of war, must assume much of that responsibility in time of peace since an integrated system of harbor defense must be in existence before the outbreak of war and must be ready for activation at short notice. Therefore, not only must the over-all plan be prepared, but the responsibilities must be clearly allocated to the various functioning groups. Each group not only fulfills its own function but is cognizant of its interrelationship with other groups. Equipment must be ready and available, and the systems tested under the conditions to be encountered.

The proposed plan to establish a system of alternate and emergency ports (see Appendix C) implies the need for certain standardized equipment and operations if shipping is diverted on short notice.

Whatever the type of attack weapon, an efficient harbor defense system should embody the following basic features:

1. Radar navigation system;
2. Harbor survey;
3. Simple standard equipment;
4. Harbor-control center.

It must be emphasized that defense in depth, including dispersal of port facilities, is the only defense against atomic attack.

II. RADAR NAVIGATION SYSTEM

In addition to the normal peacetime uses of a navigation system, there are, in wartime, several other necessary applications. Ships must be guided through defensive mine fields, along channels that have been cleared of enemy mines, and past areas in which enemy mines are known to exist but have not been removed. Mine location and destruction teams must be directed to the spots where mines are suspected to lie, while mine sweepers and patrol craft must be supplied with the best navigational information possible.

All these functions and several others could be performed by a unified radar system. Such a system would consist of a radar network covering the harbor and its approaches. The information gathered by the individual radars would give an accurate map of the harbor, with the location of all ships present at any particular time. This information would then be relayed to a harbor-control center and to all ships entering or leaving the harbor, with a video overlay showing the location of shipping channels, obstructions, possible enemy mine locations, and other danger areas. If it were not economically feasible for all ships to carry receiving equipment, the harbor pilot could carry a small portable set on board when he picked up the ship. The receiving equipment, which would be very similar to a television receiver, could be built into an easily portable, suitcase-sized equipment. In operation, the scope would present to the operator an actual map of the harbor, showing ship channels, danger areas, the position of his own ship, and the location of all other ships in the harbor. (It may be that a "talk-in" system such as is used in GCA will be the most effective. Such a "talk-in" system will be very effective in preventing disclosure of our cleared channels. The shipborne equipment required is very simple, in this case consisting of a radio receiver and a rudimentary radar beacon.)

The equipment and knowledge necessary for such a system is already in existence; a small amount of development and a large amount of production is all that is required. The radar set would probably be a rapid-scan, narrow-beam radar similar to the AN/MPG-1, although a somewhat larger sector of scan would be desirable. The receiver, likewise, should not present any great difficulties, for portable equipment similar to this has already been developed, and a satisfactory model has been constructed by RCA.

The radar network would be capable of other duties; in particular, it should be useful in tracking mine-laying aircraft and in plotting mine drops. The latter application would be especially valuable, since the problem of mine location and destruction would be made easier by an order of magnitude if mines could be located roughly by this means. Although British tests* of radar mine watching gave poor results, commercial marine radar sets were used in the tests. Since the AN/MPG-1 can observe the splash of a 6-inch shell at 20,000 yards, comparable range on mine splashes should certainly be attainable.

The location of the various stations will present some problems since, in many cases, it will not be possible to have shore installations. Particularly in those waters that are imminently threatened by mining, the shipping channels will extend beyond sight of land, and many harbors are so located that optimum locations for radar sets are not available on shore. For these reasons, thought must be given to mounting some of the radar stations off-shore, probably on moored vessels of some sort. Consideration must also be given to making it difficult for the enemy to use these sets as navigational aids for his own purposes. Since the sets are mobile, and dummy stations would be easy to set up, such concealment should not be difficult (see Appendix D, Section IV). In any case, this is only a secondary consideration, for the enemy will probably be able to DF on more convenient signals.

III. HARBOR SURVEY

Before any full-scale war starts, shipping channels must be planned and prepared, both in primary and secondary harbors, especially in those that are obvious targets for an extensive mining campaign. Harbor defenses must be so situated as to give the best possible protection; this requirement must be observed in the locating of shipping channels. The proper placement of shipping channels is also necessary to facilitate the mine-countermeasure effort; since the type of bottom is of prime importance in this

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* O. R. Study No. 7

respect, a bottom survey is an essential component of a harbor survey. The bottom survey would be useful in another respect: it would serve as a means of training mine-location crews and of testing their equipment.

Such surveys are being pursued in a limited fashion, but the present scale of effort is entirely inadequate. This information is needed for all harbors, both here and abroad, that we intend to use in a future war; it is needed immediately.

IV. EQUIPMENT

The Low Report has stated that present harbor-defense plans seem unrealistically expensive and complex. While Project Hartwell has not made an exhaustive study of all equipment used in present plans, it would seem that this conclusion is justified. However, the situation seems capable of improvement in many respects. Some items of equipment, such as heralds, UOL, and controlled mines, seem unnecessarily expensive. Less-expensive models are feasible, and reduction of unit costs would make possible a wider application of these useful devices. Another advantage that might easily accrue is that the reduction of complexity may well lead to increased reliability.

The entire situation of defensive mining should be examined critically, since, with the improved navigation that the proposed radar network would afford, wider use of defensive mines in harbors should be possible.

Defensive nets are another important link of the harbor-defense system. The ideal net should be capable of stopping both sneak craft and full-sized submarines; this implies a reinforced torpedo net, probably with explosive charges attached. Since nets are relatively inexpensive, they are useful for defense in depth.

V. HARBOR CONTROL CENTER

For effective integration of harbor defense, a control center that can handle both routine and combat information is required.

The information gathered by the radar network, listening stations, patrol craft, and other agencies would be relayed to the center, so that a central plot of harbor activity could be kept. The center would consist of several sections: traffic control, which would handle the shipping traffic entering and leaving the harbor; mine control, which would coordinate the mine-warfare effort; and a combat control, which would concern itself with the defense of the port against sneak craft and air attack. (See Annex A.)

It is evident that the radar network is an essential element of the system, since it acts as the main information source of the shipping and mine-control sections. These two sections must be closely coordinated, for the routing of shipping must take cognizance of the mining threat. If mine watching by radar proves as feasible as evidence indicates, ships could be routed past unremoved mines in the channel, or warned of the possible existence of mines near the channel. Of course, allowance must be made for underwater travel by the mine, but in relatively shallow water near channels this uncertainty will not be large.

The combat control center may need to be a more complex section, particularly if it is to include air defense. While air defense may not fall logically under direct harbor command, it is of such importance to harbor and mine defense that it must not be excluded. Furthermore, in those ports that are in danger of mining from the air, the defense area will extend far out to sea. While some doubt has been expressed concerning the extension of harbor-defense functions beyond the immediate vicinity of the harbor, in some cases such extension is necessary.

In continental U.S. harbors, the control center need not be so elaborate as that outlined above, for there is less need for a mine-defense section than in overseas harbors. As in all phases of harbor defense, the needs of each individual harbor will govern the requirements of the control center. The important fact is that the harbor control center is a vital part of an integrated harbor-defense system.

VI. HARBOR DEFENSE HANDBOOK

Harbor defense, by its nature, must be flexible and adaptable, and any scheme must contemplate the use of various combinations of component equipments and methods. A comprehensive catalogue of harbor-defense equipment is thus a necessity. No such catalogue exists.*

A complete harbor-defense handbook should be compiled, containing a listing of all equipment relating to harbor-defense, including equipment in development as well as that already in existence. Also included should be items that are necessary and feasible but whose development is not presently under consideration. Under each item there should be a comprehensive description of its capabilities and limitations, with its cost and availability at the time. The handbook should not be regarded as a manual of harbor defense; it should rather serve as a means of supplying those responsible for harbor defense with information on the status of relevant equipment and its potentialities. For this reason, the handbook should be loose-leaf, to allow for removal of obsolete data and insertion of new information.

Another important feature of the handbook should be a section of examples showing how the various items of equipment might be combined, under a variety of circumstances, to provide an integrated harbor-defense system. This particular aspect of harbor defense should be more fully emphasized, for integration of all phases of harbor defense is necessary to provide maximum protection at minimum cost.

The initial compilation of such a handbook should not be a difficult task, nor should it require a great length of time. In its preparation, an imaginative and original point of view is

* There is, however, a handbook listing mine-countermeasure equipment only.

essential, particularly in presenting the most usable and comprehensive information for alloying many possible components into integrated harbor defense systems.

VII. DEFENSE AGAINST ATOMIC WEAPONS

In planning the defenses of harbors and ports, the probability of an enemy's use of atomic weapons must receive thoughtful consideration. Unfortunately, it is far easier to predict the damage than to suggest means of defense; defense in depth must be a guiding principle for any specific harbor. But over-all defense against atomic weapons delivered by any means is impossible. Thus, one course remains: we must disperse our ports, and replace our present antiquated and vulnerable facilities with modern flexible units (see Appendix C).

The extent and nature of damage from atomic weapons will depend on whether the explosion is shallow underwater or air-burst.

The probable effect of an air burst can be estimated from the extensive data in "Effects of Atomic Weapons"(EAW) concerning damage to cities. Some information pertaining to effects of air burst is summarized in Appendix A, Table II-1.

The results of the Bikini Baker test (EAW) provide a rough estimate of the effects of a shallow underwater burst. The air blast resulting from a shallow underwater explosion of the equivalent of 20 kilotons of TNT would probably "cause virtually complete destruction or severe damage up to a little over one-half mile from surface zero, and partial destruction would extend out to somewhat over one mile." Damage in the case of ports may be more severe. Waves whose trough-to-crest height was 20 feet at one mile, and as much as 10 feet at two miles, were produced at Bikini. There are indications that an explosion in very shallow water might produce even higher waves at these distances.

The effects of radioactive contamination from fall-out and base surge are well summarized in EAW: with a light (5 mph) wind, a lethal dose of radiation may be received two miles or more from the explosion, both from fall-out and base surge. In the shallow waters of a harbor, fall-out would certainly occur; a base surge is by no means inconceivable.

Long-term contamination effects are less important, for the radiation dosage rate decreases rapidly with time. Decontamination and burying of material contaminated with longer-lived radioactive products may be difficult, however, because of the heavy physical damage that accompanies air blast and waves.

We must contemplate the possible delivery* of atomic weapons by subsurface sneak craft, or by long-range torpedoes. Defense against this type of attack is a primary responsibility of harbor defense; the principal difference when atomic explosives are involved is that the problem is much more urgent. The carrying vehicle must be detected and destroyed before it is within dangerous range of the port iself, which, from the data above, means several miles at least. Many of our devices are effective for detection of sneak craft; these must be used, particularly in the outermost detection areas. Destruction of such sneak craft is imperative; this means that mines and torpedo nets, in conjunction with patrol craft, are our most effective weapons.

Any scheme for defense in depth must take into account the possibility that the enemy may find it advantageous to use several explosions against an important port -- say, New York -- with initial attacks to clear the defenses, and to allow unhampered assault on the port itself, by subsequent explosions.

VIII. CONCLUSION

It must be emphasized that there is no easy method of harbor defense nor can any particular defensive measure be said to be more important than any other. Rather, harbor defense requires

* Project Hartwell has not considered defense against air-burst atomic bombs.

an integrated system which is flexible enough to cope with a war that rapidly changes in character. It must also be stressed again that <u>if we are to provide security for our harbors, we must start now.</u>

APPENDIX E

ANNEX A

Example of Harbor Defense System for New York Harbor

While New York will probably not be in danger of all forms of enemy attack, the following pilot study is given as an example of the probable forces necessary to defend such a major harbor if it were within close reach of enemy bases. It is assumed that the harbor will be threatened by an extensive mining campaign, and that submarines and sneak craft will attempt to enter the harbor carrying either conventional explosives or atomic weapons. Air attack will also be an imminent threat, although air defense is beyond the scope of Project Hartwell.

The first step in the defense of the harbor is the establishment of a radar net covering the approaches to the channel. Two possible systems are illustrated in Fig. E-(A)-1. In both of these, it is assumed that the radars used will scan a sector of 20° and can detect mine splashes at ranges up to 20,000 yards. These operational characteristics are approximated by the AN/MPG-1, but the angular coverage of this set is lower and should be increased. Complete coverage, as indicated in the figure, would require 19 sets, all shore-mounted (3 are not shown: 2 of these are needed to cover the port areas and one is needed to cover the approaches to Perth Amboy). Minimum coverage, as shown in the figure, requires 8 sets, 2 of which are mounted on existing lightships (2 sets, not shown, are required for port areas). The "minimum" system covers a channel leading from the port to 30-fathom water, following a route over a hard bottom most of the way.

In addition, a number of mine-location and destruction craft must be provided. If these craft were similar to those discussed in Appendix F, 3 or 4 search craft, working an average of 8 hours per day, would suffice; the number of destruction craft would be determined by the expected mining threat.

The defense of the harbor against submarines, long-range torpedoes, and midget submarines must be conditioned by an awareness that the most profitable explosive for enemy use is an atomic weapon. This means that defense in depth is mandatory, with all defense lines a safe distance from vital areas. Since sneak craft could enter through Arthur Kill and Kill van Kull, or through Long Island Sound, these entrances also must be defended.

The basic components of the defense are nets and mines. The nets should be combination submarine and torpedo nets, preferably with explosives attached, and should be deployed in depth. The mines will be shore-controlled, but need not be so elaborate as present shore-controlled mine systems; ordinary influence mines, powered from shore, may suffice. The improved navigation afforded by the radar network lessens the danger of live influence mines within a harbor; if a ship were observed to be deviating from the safe channel, it would be possible to deactivate the mine field.

Four defense areas must be set up: one outer defense area, running from Sandy Hook to Rockaway Point; and three inner defense areas, located at Elizabeth, The Narrows, and Throgs Neck.

The outer defense area should consist principally of a mine field outside a net. In addition, a line of cable-connected hydrophones should be laid, similar to the Cape Henry hydrophone system (although closer spacing of the hydrophones would be desirable, since the Cape Henry installation was not intended primarily as a defense against small sneak submarines). At the net gate, there should be a herald that can look under and behind ships to guard against sneak craft slipping by in this fashion.

The inner defense areas will consist of a pair of nets (mined, to discourage cutting), spaced at least a mile apart. Again, at the gates there should be a short-pulse herald. In addition, the entire width of The Narrows is protected by herald equipment.

The material requirements for such a defense system are given

Table E-(A)-1

EQUIPMENT FOR INNER AND OUTER DEFENSES
NEW YORK HARBOR

	Nets (yards)	Mines*	Hydrophones** in Installation	Heralds***
Sandy Hook	6,200	310	10	1
The Narrows (2 lines)	4,000			3
Elizabeth	400			1
Throgs Neck	2,400	—	—	1
Total	13,000	310	10	6

* One every 60 feet, but staggered to avoid countermining

** One hydrophone every 600 yards

*** Range at least 300 yards

in Table E-(A)-1. If additional protection is desired, such items as magnetic loops, sonobuoys, and more-elaborate controlled mines could be used, but the present system should offer adequate protection at minimum expense.

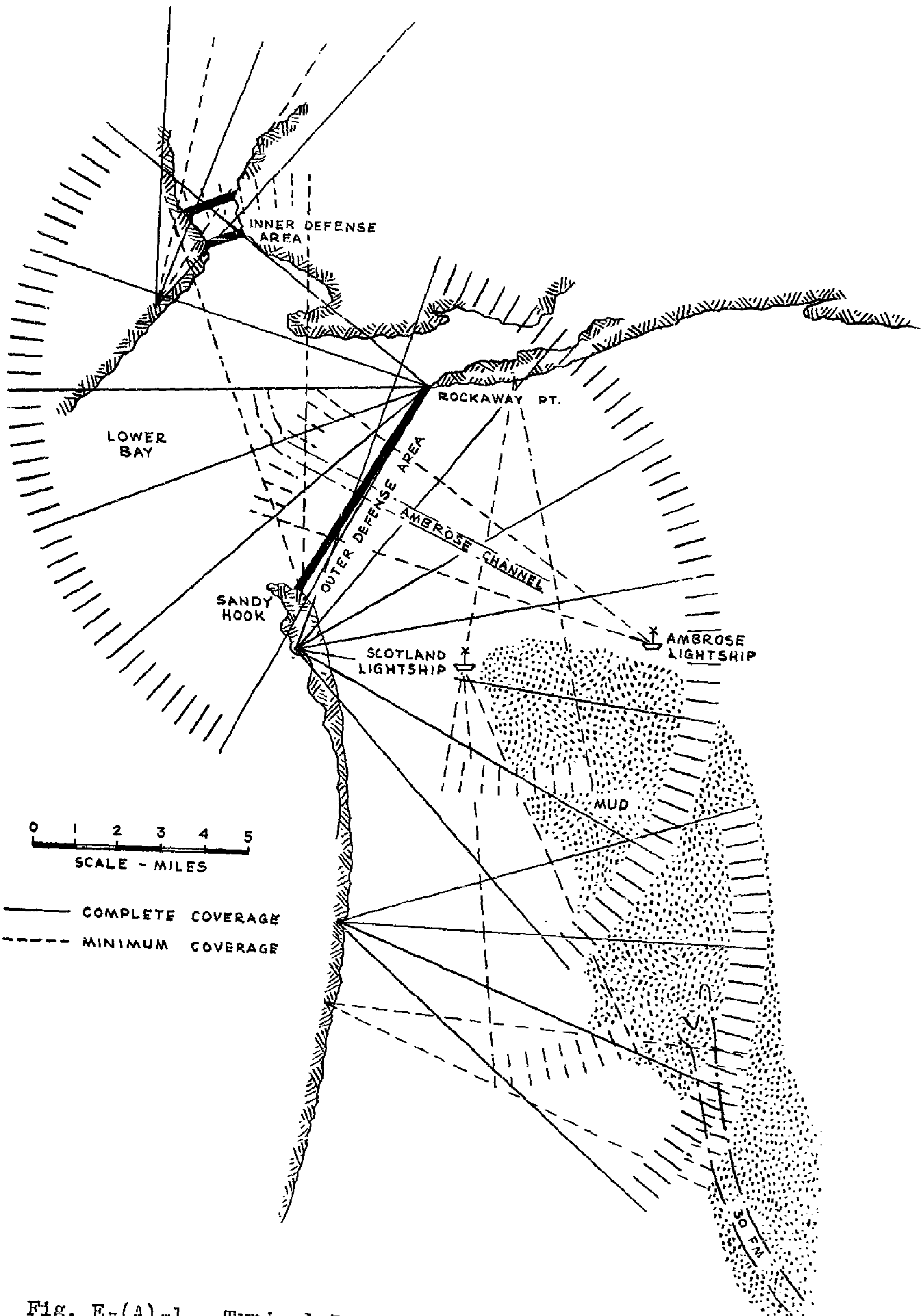

Fig. E-(A)-1. Typical Radar Coverage of New York Harbor

APPENDIX F

MINES AND MINE COUNTERMEASURES

I. INTRODUCTION

This report is based on briefings of Project Hartwell by NOL and BuShips, on considerable study of the records of mine warfare especially in World War II, on study of the Low Report "Study of Undersea Warfare" (22 April 1950), the ORO MAID Report, "Analysis of Military Assistance Program" (22 January 1950), and the OEG Report No. 62 (An Evaluation of Sea Mines as a Weapon for Use Against Submarines 17 April 1950).

The Hartwell group agrees in general with the conclusions relating to mine warfare as stated in Low Report, but recommends a more integrated handling of this important naval mission than is visualized in that report. The group likewise agrees with the major conclusion of the MAID Report, that mine warfare critically threatens our shipping supply lines to Europe, but considers it possible to counter this threat by appropriate action taken now.

The Appendix is organized in the following manner. The introductory Section I relates this report to previous reports. Section II discusses the character, scope and importance of mine warfare. Section III discusses U.S. offensive mine warfare. Section IV discusses U.S. defensive mine warfare. Section V lists the deficiencies of the present U.S. situation in mine warfare and outlines recommended corrective measures.

II. GENERAL PRINCIPLES

Certain general principles apply to mine warfare; the most important ones are the following.

A. Mine warfare is a cheap and effective mode of attack. A modern ground mine costs $1500 to make, $7000 to air-lay. Mine effectiveness can be as high as one ship casualty per 25 offensive mines laid. Approximately 3000 ships of more than 6,000,000 tons were mine casualties in World War II. Even with countermeasures that minimize ship losses, the cost of the countermeasures and the delay to shipping while channels are being cleared make mine offensives very worth while.

B. A mine offensive is most effective when the initial lay creates at least a 25 to 50 per cent threat and the field is sufficiently replenished thereafter to keep the threat at this level. This implies a maximum trained laying force in readiness at the start of hostilities. Dissipating the mine effort in small, sporadic offensives reduces the efficiency rapidly.

C. A single organization should have primary cognizance and responsibility for mine warfare in all its aspects, offensive and defensive. Development of new and improved mines and development of mine countermeasures are most efficiently done under the direction of a single leader who can coordinate the efforts of mine design and mine countermeasure. An additional point, stressed by the British, is that, for nations which themselves require ocean shipping, it is risky to put to use a new mine without a countermeasure for it in hand.

D. The mine-warfare organization must be highly flexible. Mine warfare is a rapidly changing and unpredictable art and the organization that prosecutes it must be ready to change tactics, to make and procure modifications, and to counter new and unforeseen threats on very short notice -- in other words, to optimize readiness. This principle is well documented by the British-German mine warfare interplay of World War II.* The ability to put together and deliver a few hundred special-purpose mines or to develop and apply a special mine countermeasure in a time of the order of a month pays off handsomely.

E. Mine countermeasures must be regarded as a very broad subject.

* See, for example, "Mines, Minelayers and Minelaying", by J.S. Cowie, R.N., Oxford Univ. Press (1949). The success of the British "MX" organization (p. 158 of Cowie) and the U.S. Pacific mine-modification unit is noteworthy of this connection.

Mere degaussing and sweeping are much less significant and effective than formerly. The increased sensitivity and subtlety of modern mines, and especially the advent of pressure actuation, make degaussing and sweeping alone quite incapable of countering the mine threat. Location and destruction of individual mines is now no more difficult than sweeping, and costs 1/10 to 1/100 as much per mine eliminated.* The sensitivity of mine-actuating mechanisms has been increased to the point where the mine must protect itself against natural influences and neighboring detonations; this circumstance suggests broader consideration of ship treatment (i. e., making the ship look like a natural phenomenon to the mine), and other measures that trick the mine into temporary passiveness.

F. Mine warfare is unglamorous and unspectacular, and the tendency, therefore, is to neglect it between wars. In modern war, mines and mine countermeasures are important, perhaps critical, factors. In war with an opponent such as the U.S.S.R., where little surface-ship opposition can be expected, mine warfare is a Navy mission comparable in importance to the anti-submarine mission.

Of these six principles, several are new in the sense that they hardly applied before World War II, but they reflect the increased development of the art during and since World War II and the changed international naval situation since that war.

III. OFFENSIVE MINE WARFARE

A. Ground Mines and Moored Mines

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*Assume that an ideal mine sweeper (i.e., an indestructible ship) were available at only $2,000,000, and that detection and destruction were done with simple sonar gear like the British SOD and magnetometer gear like U.S. Mk. 2 ordnance detector for searching, and UOL-type equipment for pinpointing and countermining. Then the average mine-sweeping unit costs about 10 times the average location and destruction unit, and the sweeper unit must pass within actuation range of a given mine about 10 times because of the commonly used delayed-arming and ship-count features. The location and destruction unit need approach the mine only once or twice.

Targets for U.S offensive undersea mining operations in the event of war with the U.S.S.R. will be:

(a) Soviet submarines;

(b) Soviet and satellite shipping, inland, coastal, and sea (Baltic, Caspian, Black);

(c) A relatively minor force of surface naval vessels.

Enemy ocean shipping is notable by its absence from this list. Target (a) is obviously highly important because these submarines will threaten, perhaps critically, our Atlantic supply line. Target (b) is not important, <u>except</u> for the considerable volume of petroleum-product shipping in the Caspian and Black seas, since 90 per cent of U.S.S.R. inland transport is by rail.

Regarding target (a), Soviet submarines, it is clear that mines especially designed for attack upon submarines are required. The existing U.S. stockpile mines, which have a 5000-ton merchant vessel as design target, are not optimum for anti-submarine use, although usable against submarines. Improved ground mines intended for anti-submarine use and of generally better sensitivity, reliability and flexibility are under intelligent development at NCL. However, the time interval before such new mines are in stock is estimated to be <u>not less than four years</u>, at the present rate of progress.

Kola Inlet contains the major known U.S.S.R. submarine base with direct and free access to the Atlantic, namely Polyarnoye. The Norwegian fjords are similar potential submarine bases. Of all the known Soviet submarine bases and possible future bases, these are the only ones that cannot be hampered by good conventional ground-mining techniques because of the very deep water (about 50 to 150 fathoms). The submarine-laid moored mines (the marginal Mk. 10-3 which are our only existing mine weapon for this environment) are easily swept and are magnetic needle-actuated so that they must be set to a very low sensitivity (15 milligauss) to prevent detonation by the intense magnetic storms of the auroral belt. Kola Inlet deserves more drastic mining attack than this, and the U.S. mine-laying submariners deserve more profitable returns for the risks involved. It is probable that this prime target could be effectively mined by ingenious and unconventional methods.

The laying of offensive mine fields requires well-coordinated advance planning in order to develop a maximum threat quickly at the start of hostilities. The bulk of offensive minelaying will be by aircraft, while smaller but equally essential fields will be laid by submarines. The Navy therefore needs sufficient aircraft of appropriate types to lay and maintain its planned mine fields, and these planes must be firmly allocated to and trained for this mission. Mine laying will logically be a major mission for our submarine fleet, particularly since targets for our submarine torpedoes will be few; this implies that our submarine tenders must be equipped and trained to carry, assemble and service mines as efficiently as they now handle torpedoes.

B. Land Mines and Submerged Free Mines

The offensive possibilities of ingenious and unorthodox mines and mine tactics may be far-reaching, but the U.S. is not exploiting these fields. Some types of unconventional mines may be very useful to the U.S.S.R., but U.S. countermeasures are not being prepared for such possibilities. Two such mine tactics have been considered by Project Hartwell, although, of course, no development has been undertaken. They are:

1. Small (approximately 100-pound) free, depth-keeping mines for broadcast use. Calculations made by the Project (which are available if wanted) indicate that these mines could be designed to stay below keel depth until activated by a ship passing over them, and then rise and detonate on contact. Preliminary calculations show that these mines could be made cheaply and could have an endurance of six

months or more. Such mines could be very useful to the U.S. for mining Kola Gulf, the Black Sea, the Caspian and the Baltic; but, since their usefulness to the U.S.S.R. is much greater than to us, we should certainly determine their practicability and the extent of our necessary countermeasure effort.

2. Small air-dropped, land mines for offensive use against Soviet railways. Mines that could bury themselves on air drop in a few feet of earth or rock ballast would constitute a major threat against internal Soviet transport, 90 per cent of which is carried by railway. Such mines would be more effective than bombing since locomotives as well as track would be destroyed or damaged. Any effective method of crippling the U.S.S.R. rail system will be invaluable, and specially designed small influence mines dropped by aircraft might well be such a method. These mines might weigh about 100 pounds, be laid at intervals of several miles along undefended stretches of track by low-flying aircraft, and be designed to bury themselves about 10 feet in the roadbed. They could readily be made magnetic influence-actuated by locomotives or rail cars, and need not have elaborate anti-sweep measures since sweeping would involve track damage. Booby-trap features should be incorporated because, in practice, each mine would have to be located and removed individually. The mine need be powerful enough merely to cause derailment in order to be effective.

While mine warfare against railways is not necessarily in Navy's province, it is essential that such ideas be tested and evaluated. If tests are successful, vigorous development should be started.

IV. DEFENSIVE MINE WARFARE

Defensive mine warfare considered in the most comprehensive manner includes: the laying of mines to prevent enemy craft from approaching our harbors and channels; prevention of enemy mine laying by any means; sweeping, locating and destroying individual mines; ship treatment of all kinds to reduce the probability of actuating mines; and detouring shipping around known mine locations.

Vigorous exploitation of a new kind of defensive mine warfare is important because the present type is more costly, by an order of magnitude, than offensive mine warfare. The U.S.S.R. can be expected to employ a large-scale mining effort; this we must counter in order to maintain our enormous volume of necessary shipping in the North Atlantic and Mediterranean.

The most important defensive measures probably can and should be taken before the mines are laid -- in fact, before hostilities begin. These include the following.

(1) Dispersal of harbors and construction of alternate port facilities, including feeder systems, so that we shall not be critically hampered by saturation mining of one or two large ports (e.g., New York, Liverpool).

(2) Surveys of harbor, channel and approach bottoms to determine: which areas are mineable with various mine types; which areas have clean hard bottom, soft mud bottom, debris-cluttered or rock-cluttered bottom, etc; which are the probable routes of approach of enemy mine-laying craft.

(3) Advance selection and location of channels for wartime shipping, based upon considerations of efficient disposition of anti-aircraft defenses, efficient prevention of entry of mine-laying submarines, and efficient sweeping, location and destruction of mines in channels as indicated by results of (2) above.

(4) Provision for the most precise possible navigation throughout the mine-threatened region, with due regard to prevention of enemy navigation by these means. Such a program involves full use of shore-based radar.

It is clear that these measures are logically parts of an integrated harbor-control and defense program, which can pay dividends in peace as well as in war.

Mine-laying aircraft function most accurately at low altitudes. Therefore a guiding principle in defense is to keep these aircraft flying high. An integrated system of early-warning and efficient anti-aircraft measures with radar control is essential to this purpose.

In dealing with the mines that the enemy has succeeded in laying, concentration on mine-sweeping methods would be playing into the enemy's hands, since the over-all economy probably favors the mine layer even if many ships are not sunk. Mine sweeping will be required in special situations such as naval operations, amphibious landings, or emergency use of areas by shipping when those areas have not been surveyed. But, for the broad problem of mine clearance of major wartime shipping channels, it is imperative to switch to methods involving location and destruction of individual in-channel mines.

Mine sweeping has been made an order of magnitude more difficult by the introduction of the pressure-actuated mine, for the amplitude of the pressure signature is, in the main, determined by the displacement of the body moving through the water and is hard to simulate except by an actual ship or its economic equivalent. The time has probably arrived in the evolution of mine sweeping when the only logical mine sweeper is essentially the ship at which the mine is directed. One may attempt to make such a mine-sweeping ship survive the mines it sets off by one of two methods: either it is made so rigid that the energy of the explosion will not destroy it but be reflected; or it is made to absorb the energy without impairment of buoyancy or function (as is attempted in crash-protection research). The first alternative is the only one receiving attention,* whereas an explosion-absorbent self-propelled "ship" seems technically feasible.

Mine location includes one or more of the following: tracking the laying craft by eye, radar or sonar: tracking the dropping mine; splash-watching by eye or radar; sonar monitoring of mines falling through the water; and search of the bottom by patrol boats equipped with sonar and/or magnetic and electromagnetic mine detectors. For efficient use of the information flowing in from these sources, accurate (i.e., radar) fixing of positions on the water and a central plot of all mine-location information are essential. A mine-control center is an important part of a harbor-control plan.

For limited areas with bottom conditions that make location of mines in or on the bottom very difficult (e.g., soft mud combined with much metallic debris) it may be possible and worth while to develop a network of FM sonar monitoring equipment, with high vertical definition, which look for objects falling between surface and bottom and automatically record range only.

For searching for mines buried in clean mud (no metallic debris) we should not rule out sonar means without giving short-pulse vertical-looking fathometer-type equipment a thorough evaluation.

For location of mines on or in the bottom -- as distinguished from pinpointing and destruction -- the proper general direction of development is toward cheap and simple sonar gear with short (order of one millisecond) pulses** to minimize bottom return, and toward magnetic or electromagnetic detectors of improved range. For search-

* The "X MAP" explosion-resistant cylinder costs too much, uses too strategic a material (armor-plate steel), and still has to be towed.

** A short pulse is secured simply by discharging a condensor periodically through a magnetostriction projector. The information is automatically recorded on a simple range recorder. A 3-foot sphere is detectable at 300-yard range. The shortness of the pulse is essential: at 300-yard range on a 3-foot sphere as target, the echo-reverberation ratio is 5 db for a 10-millisecond pulse, 15 db for a one-millisecond pulse, and 19 db for a 0.15-millisecond pulse.

ing channels with relatively clean hard bottoms, a unit consisting of a small boat (about 100 feet, fishing-boat type) should be considered. Equipped with three simple sonars of the British SOD type, the beams pointing ahead and 90° either side of the bow, such a unit could cover a 600-yard-wide channel and determine the location of newly dropped mines by comparing the new sonar record with a standard record. At 10 knots, the sweep rate would be 4 square miles per hour per unit.

For bottoms found unsuitable for sonar search, equipment like the Mk. 2 ordnance detector and the EDD (Electromagnetic Discontinuity Discriminator), mounted on small boats as described above, should be considered. Redesign is indicated in both equipments. It is not clear why the magnetometer of the ordnance detector is not made a total-field magnetometer or a pair of total-field magnetometers. The EDD is too fancy for its performance. Even though the sweep width of these equipments, as designed at present, is only about 25 feet, they already compare very favorably with sweeping in terms of effort per mine dealt with.

In the allocation of defensive mine craft, it will be necessary to differentiate between enemy mine-laying raids in force (as in an initial effort) and a replenishment-type sortie. This type of advanced planning will determine the disposition of locator-and-destructor boats -- whether they are best distributed among harbors, or held in a central reserve to be transported to heavily attacked areas as needed.

For certain specialized areas (Suez or Panama canal locks, etc.), bottom carpets of various kinds -- pressure-sensitive nets, explosive nets, nets for fishing up mines -- are applicable and should be given more consideration. These devices, however, do not provide an economical solution to the over-all problem.

The phase of mine location may be regarded as finished when a new object resembling a mine is known to be within a specified circle of, say, 100 feet diameter. At this stage, pinpointing and destruction boats are called into action. Such boats would logically be equipped with: more elaborate sonar gear of high resolution and short range, with scope presentation; magnetometer or electromagnetic pinpointing gear; a diver with portable locating gear, and/or a controlled underwater vehicle (perhaps wire-controlled) to investigate, countermine or grapple the mine. The boat conceived here is a more elaborate and expensive craft than a mine-search craft, and we must guard against making it large enough to constitute in itself a profitable mine target.

In order to form a rough idea of the number of mine-search craft and pinpointing-destruction craft required to counter a given mining effort, the Project has made a survey of the problem of defending the 15 major port areas of England against a mining campaign on the heaviest scale estimated in the MAID Report. According to our calculations, about 35 craft of each of the two types, strategically distributed, could handle such a campaign. A force of this size is sufficient to insure the opening of a major port area 3 days after a saturation mine attack and to keep all ports almost continuously open in the face of normal replenishment mine laying (see Table F-1). Such an estimate is made on the basis of removing all mines dropped in or near a 600-yard shipping channel.

V. DEFICIENCIES AND SUGGESTED REMEDIES

A. General

1. Mine warfare is a primary mission of the U.S. Navy in a war against an opponent, such as the U.S.S.R., that lacks a large surface naval force. At present, mine warfare is not represented commensurately with its importance by any group in top Navy planning and policy.

It is recommended that a highly placed group, with direct access to and influence upon top military planners be created.

TABLE F-I

DEFENSE OF 15 MAJOR BRITISH PORT AREAS AGAINST MINES*

Region	Area	Port	Effective Mines/Month (10% of Total)	Miles of Channel	Radars	S-L Craft	P-D Craft
I	A	Liverpool-Manchester	104	80	10	4	5
I	B	Greenock-Glasgow	21	40	5	2	1
I	B	Edinburgh	29	30	4	2	1
I	B	Total - Area B	50	70	9	4	2
I	C	Newcastle	48	16	2	1	2
I	C	Blythe	45	10	2	1	1
I	C	Sunderland	34	10	2	1	1
I	C	Hull	25	65	8	4	2
I	C	Total - Area C	152	101	14	7	6
II	D	Bristol Channel (2)	86	100	12	5	5
II	E	Plymouth	22	12	2	1	1
II	E	Falmouth-Truro	29	12	2	1	2
II	E	Total - Area E	51	24	4	2	3
II	F	Portsmouth	43	24	3	1	2
II	F	Southampton	23	16	2	1	1
II	F	Total - Area F	66	40	5	2	3
II	G	London	100	200	25	10	6
II	G	Harwich	14	10	2	1	1
II	G	Total - Area G	114	210	27	11	7
		Total - Region I	306	250	33	15	13
		Total - Region II	317	370	48	20	18
		Total	623	620	81	35	31

* Based on heaviest scale estimated in MAID report

This group should have sole responsibility for prosecuting mine warfare in all its aspects, offensive and defensive, and including all types of countermeasures. Close cooperation with the United Kingdom and other Atlantic Pact nations is essential in this field.

2. Mine warfare is being pursued in an uncoordinated and unintegrated manner. In consequence, new and unconventional methods are not being explored, and offensive mining is not being vigorously prosecuted. All these matters need to assume their proper relationship and importance in an over-all mine-warfare effort.

It is recommended that a mine-warfare facility be created. The function of such a facility would be the development of offensive and defensive mine warfare in the broadest and most comprehensive fashion, and the integration and correlation of all phases of such an effort. The facility should be so constituted as to be able to request services needed from any and all naval Bureaus. The specific activities would encompass the fields discussed in Sections III and IV.

B. Specific

The "single responsible group" and the "mine-warfare facility" visualized above would have the duty of correcting the deficiencies now existing in the mine-warfare program. The most critical of these are the following.

1. Detection, location, and destruction methods have been neglected in favor of sweeping methods. The least effective techniques have thus been emphasized. More attention should be given to the development and use of mine watches, underwater object locators (both sonar and electromagnetic), and new pinpointing and destruction craft.

2. Measure and countermeasure developments are unrealistically separated. At present, each development is tied to a specific Bureau, each progresses without reference to the other. Instead, each phase should receive stimulation from the other. Development in each aspect should parallel the other.

3. The time scale for development of new mines and countermeasures is intolerably long, particularly in view of present international conditions. Research and development must be accelerated, duplication of effort avoided. Much of the inordinate delay can be eliminated under a centralized mine-warfare group.

4. Present programs lack flexibility. Ingenious and radical methods of mine warfare, offensive and defensive, are not being explored; the present organization is not such as to encourage invention, recognition and exploitation of new ideas in mine warfare. All this, again, can be eliminated by unified direction of effort and imaginative over-all planning, so as to utilize the maximum tactical-technical interplay.

A typical radical program would be the suggested mission against U.S.S.R. rail lines. Such a plan would involve design of special-purpose mines, training of low-altitude aircraft crews, and a comprehensive evaluation test (perhaps by carrier-based aircraft).

5. The Navy probably does not have sufficient aircraft for all the mines it would need to sow. This situation is particularly hazardous, since the initial effort at the beginning of a mine offensive is often the most effective, and the maximum force would be needed in readiness. The naval aviation force for the mine lift should be immediately strengthened, and increased thereafter with increasing availability of mines.

6. The concept of mines as anti-submarine weapons has received considerable attention, but the potentialities have not been fully exploited. Current practice is to adjust conventional types for this purpose. Experience indicates that maximum effectiveness against submarines requires further design improvements. The present program, for instance, does not provide for the supply and laying of specially designed types of mines, such as those required for the Kola Inlet and similar targets. Development and procurement

of these mines should be put in hand immediately.

7. Present equipment is not adequate for a proper offensive program of submarine-laid mines. Neither is personnel in this branch equipped or trained to handle the problem. Allocation and equipment of submarines for this task and training of crews should commence immediately.

8. Mine-search patrol boats and appropriate gear for thom are not being developed and constructed. A similar deficiency holds in mine pinpointing and destruction vessels. Much originality is possible in this potentially effective field of detection-and-destruction craft. Development and procurement must be initiated.

9. Anti-aircraft weapons effective against low-flying mine-laying planes are not available or under development. In view of the threat to harbors and approaches by these planes, measures should be taken immediately to re-explore the possibility of development of such weapons using conventional and new techniques.

10. Bottom surveys of major ports and their approaches are fragmentary or lacking. The effectiveness of underwater object locators and other mine-location devices is thereby impeded. Steps should be taken to complete or to carry out such surveys in all harbors and approaches deemed essential to U.S. and allied shipping. The cooperation of oceanographers is needed in this effort; their findings will do much to delineate the type of mine-detection and destruction equipment to be used, the fixing of optimum channel locations,etc.

APPENDIX H

OCEANOGRAPHIC PROBLEMS

I. INTRODUCTION

Oceanography includes both the purely scientific and the engineering aspects of the sea. The purely scientific aspects have not been supported to the same extent as have the laboratory and land sciences. Consequently, much of the information needed in applied work is lacking, and the backlog of unexploited ideas is not so great as it should be. Since the ocean is the environment in which the Navy works, support of pure oceanography should be considered as a long-term Navy investment.

The engineering aspects of oceanography usually do not result in pieces of equipment. There are exceptional cases, such as the submarine bathythermograph and the jog-log. However, even in these cases, the more important oceanographic contribution was the recognition of the need for and possibility of such instruments.

In general, the ocean is an unfavorable environment, and an understanding of the sea is essential for success of any operation. In the case of long-established procedures, naval personnel has this understanding; but, in the case of new procedures, or in the application of new knowledge to old procedures, the professional oceanographer can be very helpful. It is, therefore, one of his functions to assist in the development program of the Navy at all points.

There are, in fact, certain problems in which the oceanographer (rather than, say, a physicist or chemist) should be the leader. These problems will be discussed in detail below.

II. SPECIFIC PROBLEMS

A. Routing of Convoys

This operational problem is a complex one, and many non-oceanographic considerations are of paramount importance.

In special cases, oceanographic considerations may be dominant, however. Particularly in the case of coastal routes, underwater sound conditions may vary greatly along routes that are otherwise not greatly different. Large rivers, such as the St. Lawrence and the Orinoco, exert an influence for a considerable, but not unlimited, distance to sea. Relatively small changes in routing may have a marked influence on the success of the anti-submarine screen in such areas, and the oceanographic factors should be given much greater weight than they received in World War II.

In the open ocean, sound conditions do not vary so widely, nor so abruptly, as in coastal waters. Other oceanographic factors, such as wind and waves still exert an influence on anti-submarine operations, however. While it is unlikely that these will often be the major factors determining the choice of transoceanic routes, they must not be ignored.

B. Oceanographic Surveys

The data on which decisions such as those outlined above must be made are not all available. Until recently, relatively little direct information on sound conditions in the open ocean was available. Apart from operational reports, which are usually incomplete, conclusions could be based only on indirect evidence and on data gathered for other purposes.

The recent survey work of the Hydrographic Office has begun to remedy this situation in the Atlantic. Similar work should be undertaken in the Pacific.

C. Experimental Work at Sea

Two kinds of oceanographic cruises are needed. The one, called a "survey", gathers data of a predetermined kind from different areas and at different seasons. On such a cruise, there is little opportunity for the development of ideas or methods, since the operation is strictly programmed, and uniformity of method is essential in order to bring out the seasonal and geographic differences.

The other type of work at sea has for its objectives the testing of new ideas, discovery of new phenomena, comparison of alternative methods and equipment, and so forth. In many cases, cruises for this purpose need not be so long as survey cruises, although this is not always true. The recent exploration of the Gulf Stream is a good example of such experimental work.

Experience shows that it is not profitable to combine survey and experimental operations. The systematic nature of the survey and the necessary flexibility of the experimental program are contradictory. In operating an experimental laboratory vessel, everything should be sacrificed for flexibility of the work. The scientist should not be required to schedule his work months in advance; he must be given great latitude for improvising operations after departure from port.

D. Harbor Surveys

The surveying of harbors and their approaches is of importance in many connections. In well-established harbors, soundings and charting of channels and anchorages may be taken for granted, but other items are not always fully known.

The possibility of radioactive contamination is a new threat that makes it necessary to understand the circulation of water in a harbor in greater detail than has ever been attempted in the past. This data is necessary for damage control in the event that our own harbors should be contaminated, as well as for planning possible offensive operations against enemy harbors. Before routine surveys for these purposes can be undertaken, extensive experimental work in one or more harbors will be necessary.

This field work can be supplemented by experiments with scale models of the harbor, as was done in the case of Bikini Lagoon.

Other types of surveys are needed to plan harbor defenses, mine-countermeasure operations, and so forth.

E. Preparation of Charts and Other Intelligence Materials

The need for special charts of the oceans and harbors of the world is now well recognized. Examples of such charts are the sonar and bottom-sediment charts prepared during World War II.

In many cases, some of the data needed for these charts are available, but very often the material is incomplete. The objective of the surveys must be to complete and improve the existing files of data.

There has been considerable discussion of methods whereby the present sonar charts could be improved. No conclusion has been reached, largely because there is no one number that measures the quality of sonar conditions. It appears preferable to prepare several kinds of charts, each portraying one of the basic oceanographic quantities such as temperature, wind, etc. This division will complicate the use of the charts, but it does not seem advisable to make extensive revision of the sonar range charts at this time.

There is great need for charts of temperature and salinity in coastal areas, such as those traversed by our commerce with South America. Although these areas were at times heavily attacked by submarines during World War II, they have not yet been adequately surveyed, much less charted.

Bottom topography has been used as an aid to navigation for centuries, but the modern recording echo-sounder offers the possibility of marked improvement in this method. The preparation of charts for this purpose is delayed by incompleteness of the data.

F. Studies of Surface Waves

Considerable advances have been made in the study of ocean waves, but much remains to be done.

During World War II, attention was concentrated on long-period waves that cause surf. Methods were developed for forecasting surf during amphibious operations. The data for these forecasts were obtained from weather maps. These methods could now be improved and the converse problem, of using observations of surf to supplement meteorological observations, has also been studied.

Another important problem in this field is that of sea clutter, which will be limiting in A/S radar operations. This is determined by waves of shorter period, which have been inadequately studied in the past. The study of this problem will require cooperation between oceanographers and those engaged in the development of radar gear. However, the dynamics of the sea surface is an essentially oceanographic problem, and the results of its intensive study may well have unexpected applications. For example, it may prove possible to spray limited areas with oily substances and thus reduce sea clutter for a limited time.

G. Ambient Sea Noise

Ambient sea noise will become an important problem if sonar self-noise can be reduced. This can be done by using a quiet S/M as listening platform, and possibly by using bottom-mounted or variable-depth installations.

Its study, again, will require the cooperation of physicists and oceanographers; but, since much of the experimental work must be done at sea, the experience of the latter should be utilized fully.

Existing data on ambient noise in the lower-frequency ranges are inadequate. It is still debatable whether ambient noise diminishes with depth. Its cause is still the subject of speculation rather than knowledge, although it is known that some components are due to marine animals. After advances have been made in these matters, it may become necessary to survey the oceans for the purpose of obtaining the geographical variations of ambient noise.

In general, oceanographic experimentation during the last years has been very fruitful of scientific results, some of which have already found direct application to naval problems. The bottleneck has been manpower and facilities, rather than an intrinsic barrenness of the field.

APPENDIX I

UNDERWATER PROPULSION SYSTEMS

I. INTRODUCTION

This appendix contains information gathered as a result of a short survey of underwater propulsion systems for submarines and torpedoes. The purpose of the survey was to provide background information for the personnel of Project Hartwell -- information that would enable this group to assay more intelligently the offensive performance of U.S.S.R. weapons systems and the counter-offensive performance of U.S. weapons systems.

No attempt is made to specify the propulsion systems to be used in particular weapons; the Power and Propulsion Panel Report* is a critical evaluation of submarine propulsion systems which is order-of-magnitude more comprehensive than this brief survey. Also, the torpedo-development picture will shortly be subjected to intensive scrutiny by the recently organized "Harnwell Committee". Consequently, Project Hartwell has felt that any duplication of the functions of these two groups would be wasted effort.

This survey is based upon U.S., British, and German developments. Many of the recent U.S. developments stem from German work, and, in these cases Soviet activity probably closely parallels our own. Since under-water weapons constitute the major Soviet strategic offensive potential, it is probable that the Soviets have pushed intensively the development of submarines and torpedoes and have outdistanced the U.S. in this field.

An underwater propulsion system consists of the power plant and the energy source -- usually a fuel and oxidant. A number of different power plants can be operated with a given fuel and oxidant and *vice versa*. Consequently, it is convenient to

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*Refer to numbered references, pp. 17 and 24.

discuss independently the characteristics of the various types of power plants and of the possible fuel and oxidants, and then to evaluate the performance of optimum combinations.

II. POWER PLANTS

The power plants that might be used for submerged propulsion may be divided into three classes:

A. Thermal: these include reciprocating engines and turbines in which a fuel and oxidant are burned.

B. Electrical: chemical reactions, carried out in a battery, generate electric power which is converted into propulsive power by means of electric motors.

C. Jet systems: these are the waterborne counterparts of the pulse-jet, the ram-jet, and the rocket.

A. Thermal Power Plants

The basic features of underwater thermal power plants are the same as their surface prototypes. Depth operation requires the expulsion of exhaust products into a high-pressure ambiance, a condition not ordinarily imposed on surface engines; and the consumption of an underwater plant must be measured in terms of fuel and oxidant instead of just in terms of fuel. The space available for the submerged propulsion power plant is severely limited, but in a torpedo the restrictions are more stringent than on a submarine.

1. Torpedo Thermal Power Plants

A torpedo power plant should be simple, compact, efficient, and cheap. These criteria conflict, and a compromise solution results. Either a reciprocating engine or a turbine may be used as a torpedo power plant. Table I-1 gives the operating characteristics of a number of torpedo thermal power plants now in operational use. These are all shallow-running torpedoes which

Table I-1

OPERATING CHARACTERISTICS AND PERFORMANCE DATA
FOR TORPEDO ENGINES IN OPERATIONAL USE

Number	Engine	Torpedo or other Designation	Type	Combustion Process	Inlet Temp. (°F)	Inlet Press. (psia)	rpm	Max. HP	Engine and Transmission Weight (lb.)	Engine and Transmission Weight (lb./max. HP)	Fluid Consumption (Lb./HP-hr.) Fuel	Oxid.	Dil.	Total
1	British 21"	Mk VIII & IX	4-cyl. radial	ext. comb.	--	845	1190	320	265	0.83	0.80	11.00	4.0	15.8
2	British 21"	Mk VIII & IX	4-cyl. radial	semi-int. comb.	--	845	1310	400	265	0.66	0.59	7.70	--	8.3
3	British 18"	Mk. XI - XV	4-cyl. radial	ext. comb.	--	960	1235	230	162	0.70	0.74	10.90	4.0	15.6
4	British 18"	Mk. XI - XV	4-cyl. radial	semi-int. comb.	--	715	1220	230	162	0.70	0.87	7.96	--	8.8
5	French	1926 W	turbine	ext. comb.	2370	520	15000	160*	190	--	2.4	11.2	--	13.6
6	U.S.A.	Mk. 13	turbine	ext. comb.	1350	500	13400	175	155	0.89	1.46	11.40	3.90	16.8
7	U.S.A.	Mk. 17	turbine	ext. comb.	1300	550	13300	500	350	0.70	1.72	9.90	--	11.6
8	U.S.A.	Mk.-EX 25	turbine	ext. comb.	1800	500	18000	300	170	0.57			--	11.2
9	German	Gerat 30	turbine	ext. comb.	950	550	25000	500	300	0.60	Tested on Steam			
10	Japanese	Type-91	8-cyl. radial	ext. comb.	--	--	1060	108**	--	--	1.23	14.8	3.32	19.4
11	Swedish	Lesto	turbine	ext. comb.	--	620	64000	400	411	1.03	1.00	13.8	9.60	24.4
12	German	G7a	4-cyl. radial	ext. comb.	--	590	1490	300	342	1.44	0.91	10.9	3.82	15.6

* Data from Reference (19)

** Horsepower developed in torpedo under typical operati[ng] conditions; maximum possible horsepower not known

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had been adopted for fleet use by the end of World War II. Much better thermal power plants are under development. Table I-1 shows that, at a comparable state of development, the pounds per horsepower generated by a turbine or a reciprocating engine are roughly the same when all the necessary components (including combustion chamber, speed-reducing gears, etc.) are included. In general, with the same fuel and oxidant, a turbine will be somewhat better than a reciprocating engine when the comparison is made on the basis of weight per horsepower. On the other hand, both the efficiency (measured in terms of pounds of consumables per horsepower-hour) and the operational characteristics at high back pressures of a reciprocating engine are usually better than for the turbine. Although none of the power plants of Table I-1 was intended for deep-depth operation, either the reciprocating engine or the turbine can be designed to work at high back pressures. The NOL-Ranger V-90 torpedo engine has been successsfully operated at depths ranging to 1,000 feet in tests conducted at Key West. This engine does not employ any special mechanism to overcome the effect of high exhaust pressures. The engine is designed to tolerate high back pressures without a material decrease in the horsepower. The fuel and oxidant consumption of the NOL-Ranger engine increases as the operating depth is increased. Any thermal power plant will suffer a similar decrease in efficiency with increased depth unless a special exhaust system is provided. In view of the space limitations imposed on a torpedo power plant, such an exhaust system will be difficult to install. It may be possible to provide an artificial constant-pressure exhaust sump for the power plant in the following way. The exhaust gases are cooled by the direct injection of sea water, and the water vapor in the gases condensed. A liquid pump then raises the sump-water pressure from its fixed, low value (say 30 psia) to ambient pressure and discharges the water overboard. A gas compressor raises the pressure of the non-condensable gases and pumps them overboard. No detailed studies of the application of such a system to torpedo propulsion appear to have been made. The practicability of the scheme is strongly dependent upon the composition of the exhaust gases. These gases must be largely water vapor, which immediately implies the use of peroxide or oxygen as the oxidant, and may require hydrogen (generated by a water-reactive fuel) as the fuel.

The expendable consumption of any power plant is strongly dependent upon the fuel and oxidant supplied. Either the turbine or the reciprocating engine can be operated on a wide variety of fuels and oxidants. The use of hydrogen peroxide and a hydrocarbon fuel has been explored most extensively. Water-reactive fuels have also been tested. Encouraging results have been obtained using lithium as the fuel for the prototype turbine-pump jet system for the Mk. 40 torpedo. The major difficulty is the solid residues formed by the metal-water reaction. These residues clog the passages of the power plant and reduce its efficiency.

2. Submarine Thermal Power Plants

A thermal power plant for submarine use can be made more efficient than a torpedo power plant. The additional space available and the greater emphasis on low fuel and oxidant consumption permit the use of more complicated, but more efficient, systems. A special exhaust-disposal system involving the creation of a constant-pressure exhaust sump by means of a jet condenser and overboard liquid and gas pumps is feasible.

Both reciprocating engines and turbines can be used for submerged submarine propulsion. In addition, the underwater plant can be designed to act as a surface propulsion system with air replacing the stored oxidant. By the end of World War II, the Germans had made considerable progress toward the development of thermal power plants for underwater propulsion. The Allies, including the U.S.S.R., obtained the details of these developments and the experimental units built by the Germans. The German developments were based upon two types of units: the modification of standard submarine diesel engines for use with stored oxidant as well as with atmospheric air -- the "Kreislauf System"; and the development of a turbine power plant (the "Walter Cycle") which would use hydrogen peroxide as the oxidant. Neither of these developments had been completed by 1945. The Kreislauf system had been used successfully in tests of a Daimler-Benz engine with liquid oxygen and recycled exhuast gases used in place of atmospheric air. The problem of the storage of liquid oxygen on board a submarine had not been completely solved, however, and minor technical features of the power plant itself required revision.

An experimental version of the Walter cycle was undergoing test on board a submarine by the end of World War II. The turbine built for this purpose was poorly designed, and the efficiency of the plant was low. Considerable progress had been made in the storage of hydrogen peroxide on board the submarine. This was done by putting plastic bags between the inner and outer hull of the submarine. The bags were initially filled with peroxide, and, as the oxidant was consumed, the bags collapsed. An equivalent volume of sea water flowed into the storage space. In this way, changes in the buoyancy of the submarine were minimized.

After World War II, the United States, Great Britain, and presumably the U.S.S.R. instituted programs designed to develop thermal power plants for submerged submarine power plants. The U.S. Navy is currently carrying on simultaneously the development of the Kreislauf cycle, a modified Walter cycle, a closed-cycle gas turbine, and a semi-closed cycle gas turbine. In addition, a free-piston gas-generator development has been supported on a low priority basis.

The Kreislauf or modified Kreislauf cycle is the quickest and cheapest way to obtain a high-power submerged power plant. The main component, the submarine diesel engine, is available, and the additional modifications invoke straightforward engineering. A sketch of a simple Kreislauf cycle using liquid oxygen is shown in Figure I-1. The major disadvantage of this cycle is the low power and large volume associated with the main diesel engine now installed on fleet submarines. The simple Kreislauf cycle is not particularly attractive when hydrogen peroxide is used as an oxidant. It fails to exploit the fact that peroxide may be pumped as a liquid to a high pressure, decomposed, and the resulting high-temperature and -pressure gas sent to an expansion engine where considerable net power may be obtained. These objections to the simple Kreislauf cycle may be overcome largely by the addition of a second component to the system in the form of a small but high-output "steam" turbine or reciprocating expansion engine as shown in Figure I-2.

Table I-2 compares the performance of the simple and modified Kreislauf cycles when the GM278-A two-stroke diesel engine (typical of present U.S. submarine diesels) is used as the main engine. In addition, the estimated performance of the Kreislauf system when a new high-output diesel is used as a substitute for the outdated GM-278-A is shown.

A complete Kreislauf has not been operated in the U.S., but the components have been tested in one form or another and shown to be operable. The U.S. Navy believes that, if necessary, it could begin production modifications for the simple Kreislauf in 1951. The U.S. modified Kreislauf is still in the paper-proposal stage, and it would take 3 years to bring it to the production stage.

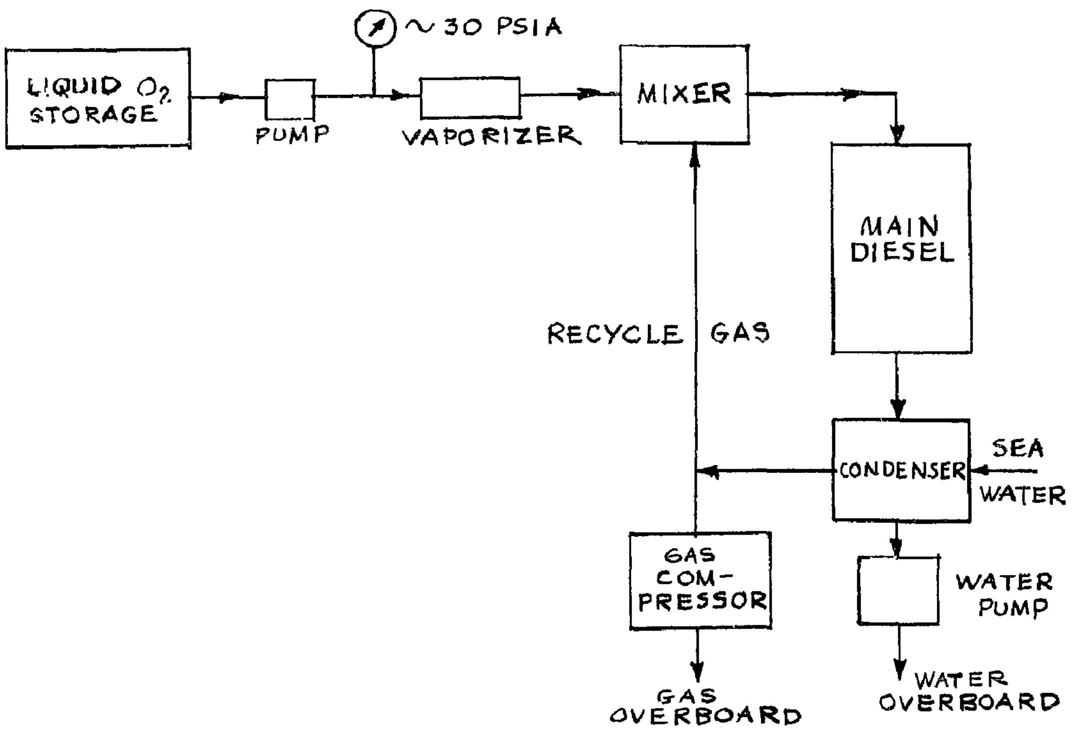

Fig. I-1. Schematic Diagram of Simple Kreislauf Cycle

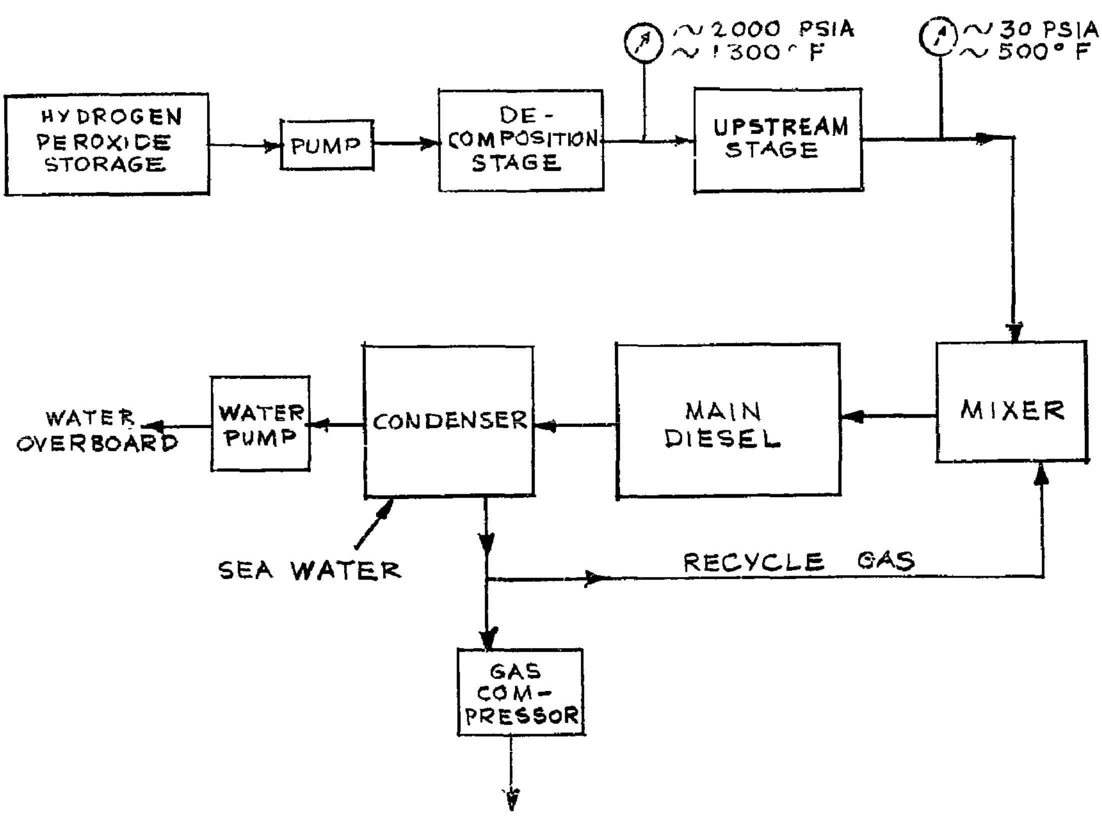

Fig. I-2. Modified Kreislauf Cycle

Table I-2

COMPARISON OF PERFORMANCE OF KREISLAUF-SYSTEM POWER PLANTS

System	Fuel	Oxidant	S.E.C.*	Lb./HP**	Ft^3/HP***
Simple Kreislauf (GM278-A Diesels)	Diesel	Liq. O_2	3.1	16	0.2
Simple Kreislauf (GM278-A Diesels)	Diesel	90% H_2O_2	6.7	16	0.2
Modified Kreislauf (GM278-A Diesels) and Upstream Stage	Diesel	90% H_2O_2	4.7	11	0.14
Modified Kreislauf (New Diesel and Upstream Stage)	Diesel	Liq. O_2	2.4	5	0.1
Modified Kreislauf (New Diesel and Upstream Stage)	Diesel	90% H_2O_2	3.7	5	0.1

* Pounds of fuel and oxidant per HP-hour at 500-foot depth

** Weight of main diesel and upstream stage per horsepower; does not include condenser or overboard pumps

*** Envelope volume of main diesel and upstream stage per horsepower; does not include condenser or overboard pumps

Data based on Reference (6)

The steam (modified Walter) cycle, the closed-cycle gas turbine, and the semi-closed cycle gas turbine developments for submerged propulsion are modifications of their surface counterparts. The major changes involve means for exhaust-gas disposal into a high-pressure ambiance and the use of stored oxidant instead of atmospheric air. The exhaust-gas disposal systems proposed are similar to those intended for Kreislauf operation -- a condenser and liquid and gas compressors.

The temperatures of the working fluids are controlled by recycling gas or liquid water. The use of any of these systems by either the U.S.S.R. or the U.S. would involve the complete replacement of existing submarine power plants. The performance characteristics of these cycles are roughly the same as those shown for a modified Kreislauf system employing a new diesel engine and an upstream stage in Table I-2. The U.S. Navy expects to complete the development testing of these three cycles by 1952. One of these cycles could be installed in a new submarine (SSX) by 1955.

The only thermal power plant that appears to be superior to a modified Kreislauf with new diesel engines or the gas turbine plants is a system that employs a free-piston gas generator-expansion turbine in place of the main diesel engine. A schematic drawing of the free-piston gas generator-turbine is shown in Figure I-3. The gas generator operates as a diesel engine but does not deliver any net work. Instead, it generates and supplies hot, high-pressure gases to a gas turbine. The net power is generated by the turbine. The gas generator exhibits the high thermal efficiency of the diesel cycle, and the power unit embodies the simplicity and compactness of the gas turbine. This unit is more compact than a diesel engine (i.e., lower weight and volume per horsepower), and is more efficient than the gas turbine. Prior to World War II, free-piston gas generator-turbine units were tested in Germany, France, and Switzerland. After this war, at least three developments were initiated in the U.S. The Navy-sponsored Lima-Hamilton Corp. project resulted in an experimental prototype unit which is now undergoing further testing at the Naval Experiment Station at Annapolis. This engine is not ready for production and probably considerable development will be required before a satisfactory prototype results. It is estimated that the use of a free-piston gas generator-turbine in place of a modern diesel engine would reduce the weight of fuel and oxidant consumed per brake horsepower-hour by 20%, and decrease the volume per horsepower by roughly the same amount.

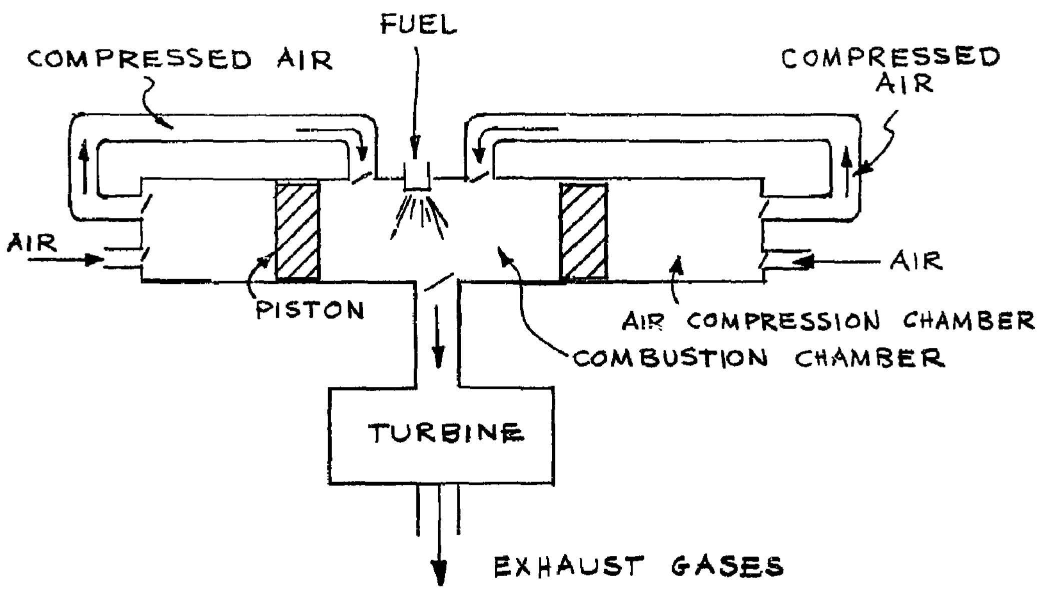

Fig. I-3 Schematic Drawing of Free-Piston Gas Compressor

B. Batteries

Theoretically, batteries are an attractive source of underwater power. They are quiet, they can be used to supply power directly to electric motors, and their operation is insensitive to back pressure, and hence, to depth of submergence. Most batteries generate little if any gaseous products, and, consequently, there is no wake problem and no need to compress or absorb non-condensable exhaust products. For a number of possible fuel-oxidant combinations, the theoretical expendable consumption is very low as shown in Table I-3.

Table I-3

THEORETICAL (100% Efficiency) OF FUEL AND OXIDANTS FOR BATTERIES

Reaction	Lb./BHP-Hr.
$H_2 + 1/2\ O_2 \longrightarrow H_2O$	0.45
$H_2 + Cl_2 \longrightarrow 2HCl$	1.6
$H_2 + H_2O_2 \longrightarrow 2H_2O$	0.65
$Mg + Cl_2 \longrightarrow MgCl_2$	0.80

These are only a few of the possible reactions that might be used to develop power in an electrolytic cell. These values are, however, representative of the theoretical performance, and serve to point out the fact that, if reasonable efficiencies could be obtained, a battery might be a successful long-duration power supply.

It is convenient to classify batteries into three types.

a. <u>The primary or self-contained "package" battery</u>:- This is typified by the familiar "dry cell". In the primary battery, the reacting chemicals are stored inside the cell. When these chemicals are used up, the entire battery must be replaced.

b. The secondary or storage battery:- This is typified by the lead storage battery. Like the primary cell, the storage battery carries the reacting chemicals as an integral part of the cell. The cell reactions are at least partly reversible, however, and the cell may be recharged if supplied with externally generated electric current.

c. The fuel cell:- There is no familiar commercial prototype of this battery. In the fuel cell, the bulk of the reacting chemicals are carried outside the electrode compartments and are supplied to the cell as needed. The products of the reaction are removed as they accumulate. The total power generated by this battery is limited only by the quantity of chemicals that can be carried outside the cell.

1. Presently Available Batteries

a. Primary Batteries

Although there are a number of commerical primary batteries, at the present time there are only three primary batteries that can be considered suitable for underwater propulsion. They are the magnesium-silver chloride-sea water cell, the magnesium-copper chloride-sea water cell, and the zinc-sodium hydroxide-silver oxide cell. The performance of these cells is contrasted with that of a typical dry cell in Table I-4.

Table I-4

AVAILABLE PRIMARY CELL PERFORMANCE

Battery	Lb. Battery/HP-hr.	Ft^3 Battery/HP-hr.
Dry Cell	41	0.33
Mg-Sea water-AgCl	20	0.4
Mg-Sea water-CuCl	25	0.5
$Zn-NaOH-Ag_2O$	25	0.25

Table I-5

DATA ON THE MAGNESIUM-SEA WATER-SILVER CHLORIDE BATTERY FOR TORPEDO PROPULSION

Manufacturer

General Electric Company, Schenectady, New York

Output

455 amp. at 135 volts for 15 minutes
20.6 HP-hr. (82.2 HP)

Materials

Magnesium--approximately 40 pounds
Silver chloride--approximately 230 pounds

Weight

Battery only, approximately 400 pounds; including pressure bulkheads, etc., approximately 700 pounds

Construction

Five sections in parallel, each furnishing 90 amp; section consists of 110 cells in series with plates 11" by 11-3/4"

Cell thickness, 0.045", consisting of Mg sheet 0.010", space 0.017", silver chloride sheet 0.017", silver foil 0.001"; units stacked against each other; separation by glass heads approximately 0.025"; section thickness 5", with end plates about 5-1/2"

Battery cooled and hydrogen removed by circulating about 1,000 pounds of sea water per minute.

Operating Data

Volts per cell, 1.23
Current density, 0.7 amp. per sq. in.
Leakage losses around plates through electrolyte (short-circuit losses) about 10%

Cost

Approximately $15,000

Data from Reference (7)

The sea water cells were developed during World War II. At present, the Mg-AgCl cell is being used as the power source for one version of the experimental Mk. 35 torpedo. Table I-5 gives the data on this cell. The cell reaction is $Mg + 2\,AgCl \longrightarrow MgCl_2 + 2\,Ag$, carried out in the presence of a sea water electrolyte. Although the cost of the silver used in this battery is high (about \$3,000), the major expense is due to [illegible] manufacturing techniques required. The thin electrodes (~ 0.02" thick) and the narrow electrode spacing (~ 0.02") (employed to lower the electrolyte resistance to a reasonable value) result in an extraordinarily high man-hour requirement for fabrication of the battery. Present costs above the materials used are \$10,000 per battery, representing about 4,000 man-hours. Even on a large-production basis, the total cost of the battery is estimated at \$9,000. In the present version of this battery, side reactions and electrolyte resistance reduce the cell efficiency and result in a high heat generation and hydrogen gassing. (The actual cell voltage is 1.23, in contrast to a theoretical of 2.57 and 1,000 pounds of sea water per minute are circulated to remove the heat and hydrogen.) It is possible that further development will increase the cell efficiency and reduce the battery weight from its present value of 20 lb./HP-hr to a figure near 15 lb./HP-hr.

The magnesium-sea water-cuprous chloride battery uses the reaction

$$Mg + 2\ CuCl \longrightarrow MgCl_2 + 2\ Cu$$

in the presence of a sea water electrolyte. The construction and operation of this cell are similar to the Mg-AgCl cell, but the copper chloride cell is not so completely developed. The raw-material cost for the copper cell is considerably lower than for the silver cell, but the fabrication costs are nearly the same. Further development may lower costs to \$6,000 for a 20 HP-hr battery (Mk. 35 torpedo) on a production basis.

The zinc-sodium hydroxide-silver oxide cell (the Yardney cell) is easier to fabricate than the sea water cells. Small-scale prototypes have been built and tested. There is a distinct possibility that this cell can be made rechargeable. It is estimated that the silver oxide cell would cost about one-half as much as the silver chloride cell. Considerable work will be needed before the practicability and service performance of this cell will be known.

b. Storage Batteries

There are three developed storage batteries: the lead-sulfuric acid cell, the Edison cell, and the nickel-cadmium cell. In addition, the Zn-NaOH Ag_2O (Yardney) cell may be a useful storage cell. The performance of these cells is shown in Table I-6.

Table I-6

STORAGE-BATTERY PERFORMANCE

Battery	Lb./HP-Hr.	Ft^3/HP-Hr.
Lead-acid	75	0.5
Edison	60	
Nickel-Cadmium	65	
Zn-NaOH-Ag_2O (Yardney cell)	25	0.25

As a primary energy source, the developed storage batteries are inferior to the package cell. However, the Yardney cell may prove to be a considerable improvement. At present, development of this cell is proceeding slowly with only limited funds available. Rechargeability is desirable in a submarine power supply, provided that the performance penalty is not excessive and the tactical mission of the submarine permits recharging during the cruise. In a torpedo, the main advantage of a storage cell is for training and testing.

c. Fuel Cells

There are no fuel cells available today that are suitable for submerged propulsion. There is only one true fuel cell in operation -- a small cell developed by the National Carbon Co. for use in miners' lamps. This cell utilizes the reaction

$$H_2 + Cl_2 \longrightarrow 2\ HCl,$$

which is carried out in a hydrochloric acid electrolyte. The hydrogen and chlorine gas are continuously fed to the cell electrodes. Although this cell is scarcely beyond the laboratory stage and employs two gases (which, if stored as such, would be difficult to handle), it is an important development. The electrolyte resistance is low, and the electrode reactions take place with a minimum of polarization and side reactions. Consequently, the efficiency of the cell is high; about 80% of the theoretical power is developed by the operating cell. Current densities of 200 amperes per square foot are easily obtained at the chlorine electrode, and similar values can probably be attained at the hydrogen electrode. The high current density, coupled with a closed circuit emf of the order of 1.25 volts per cell, implies a compact cell unit. Further, as discussed later, the hydrogen and chlorine need not be stored as such but may be carried in the form of relatively inert chemicals with no sacrifice in expendable consumption. In addition to these characteristics of the hydrogen-chlorine cell, the fact that it operates with reasonable efficiencies is a good sign and indicates that other fuel cells could be developed if such a program were pushed.

A cell developed before World War II that approaches a fuel cell is the "air cell" of the National Carbon Co. This cell employs a zinc anode, a sodium hydroxide electrolyte, and a porous carbon cathode that absorbs oxygen from the air and functions as an oxygen electrode. At present, these cells are fabricated for low rates of drain and weigh about 20 lb./HP-hr. of output, excluding the oxygen consumed. The technical staff of National Carbon believe that forced feeding of pure oxygen to the carbon electrode could be accomplished, and that a high-drain battery could be fabricated with a dry weight of 12 lb./HP-hr. Water would be added to the battery just before use, and oxygen would have to be carried in some form. However, the oxygen is a small portion of the battery weight. This cell shows that a successful oxygen electrode can be developed, but considerable effort would be needed to develop this cell into a useful battery for submerged propulsion.

The National Carbon Co. has also developed a second semi-fuel cell. This battery employs a zinc cathode, an ammonium chloride electrolyte, and a porous carbon anode through which chlorine gas is fed to the system. This battery developed 16 HP-hours and weighed less than 1,000 pounds. Further work could reduce this weight. Although this battery was relatively cheap, its development was dropped because of the possible hazards associated with the storage of chlorine.

2. Future Battery Developments

Table I-7[7] gives the results of some estimates as to what might be accomplished in future battery developments. They are based on the extrapolation of a combination of existing theoretical and practical data. The subheadings "pessimistic", "optimistic", and "probable" indicate the degree of uncertainty in the estimate. For the fuel cells, all operating data except the fuel consumption are for the battery only. The externally stored fuel is not included. The package-cell data include the battery and the fuel. If actively prosecuted, the probable values listed in Table I-7 might be achieved in a practical battery within 10 years.

Any detailed discussion as to how the estimates of Table I-7 might be achieved would be out of place in this summary. However, one suggestion[7] will be outlined in order to orient the reader.

Very small prototypes of the hydrogen-chlorine fuel cell have been operated. There is reason to expect that a large cell can be built, although the practical engineering problems are numerous and difficult. Hydrogen and chlorine are undesirable

Table I-7

ESTIMATED POTENTIALITIES OF BATTERIES

Degree of Uncertainty	Volts/ Cell	No. Cells/ Ft.	Current density (amps/ft^2)	Lb./* HP	Ft^3/* HP	Lb./HP-Hr.
			FUEL CELLS			
Pessimistic	1	36	100	50	0.25	4**
Optimistic	4	48	600	0.8	0.008	1**
Probable	1.5	40	275	6.5	0.054	2**
			PACKAGE OR SEMI-PACKAGE CELLS			
Pessimistic	1	90	100	25	0.1	20***
Optimistic	4	250	500	0.24	0.002	2***
Probable	2	100	200	3.6	0.024	10***

* Includes allowance for case and connections
** Pounds of externally stored fuel per HP-hr
*** Pounds of battery and externally stored fuel (if any)

Data based on Reference (7)

chemicals, and the storage of large amounts of these materials on board a submarine is probably impracticable. It is possible, however, to store chemicals that can be used to generate both hydrogen and chlorine. One scheme is the following.

Silicon, sodium hydroxide, sodium chlorite, and a small amount of acid would be stored on the submarine. All these materials are solid or liquid, and are manufactured in large quantities. The silicon-caustic reaction is used to generate hydrogen by means of Reaction (1) of Table I-8. Chlorine is generated from the sodium chlorite by means of Reaction (2). The chlorosulfonic acid used would be stored on board the submarine, but the hydrochloric acid is obtained from the cell Reaction (3). A schematic diagram of the system is shown in Figure I-4. This scheme appears

TABLE I-8

HYDROGEN AND CHLORINE GENERATION ON BOARD A SUBMARINE*

Hydrogen Generation — Reaction

$$2NaOH + 4Si + 20H_2O \longrightarrow Na_2Si_4O_9(\text{dissolved}) + 13H_2O + 8H_2 \qquad (1)$$

Chlorine Generation

$$16HCl + 4NaClO_2 + 0.326ClSO_3H + 197.5H_2O \longrightarrow 4NaCl + 0.326H_2SO_4 + 0.326HCl\ (\text{dissolved}) + 205.1H_2O + 8Cl_2 \qquad (2)$$

Battery Operation

$$8H_2 + 8Cl_2 + 197.5H_2O \longrightarrow 16HCl + 197.5H_2O + 326\ \text{HP-hr.} + 269{,}500\ \text{BTU (heat)} \qquad (3)$$

Fuels Used

$NaOH + Si$ for hydrogen, 192 pounds

$NaClO_2$ (+ $ClSO_3H$) for chlorine, 400 pounds

Total weight fuels, 592 pounds

Energy Produced

326 HP-hr. at motor terminals

261 HP-hr. shaft with 80% motor efficiency

Specific Fuel Consumption

1.76 pounds/electrical HP-hr.

2.26 pounds/SHP-hr.

Heat Generated in Battery (diff. ΔH and ΔF, int. resist., etc.)

269,500 BTU

Material to Absorb Heat

4139 pounds (mostly H_2O)

Temperature Rise in Battery Fluid

$$\frac{269{,}500}{4139} = 63°F \text{ (with no other cooling)}$$

Fluids Pumped (pounds)

Hydrogen generator,	in	360		
Hydrogen generator,	out		536	
Battery,	in	3555		
Chlorine generator,	out		3971	
Total in		3915		15/SHP-hr.
Total out			4507	17.3/SHP-hr.

*From Reference (7)

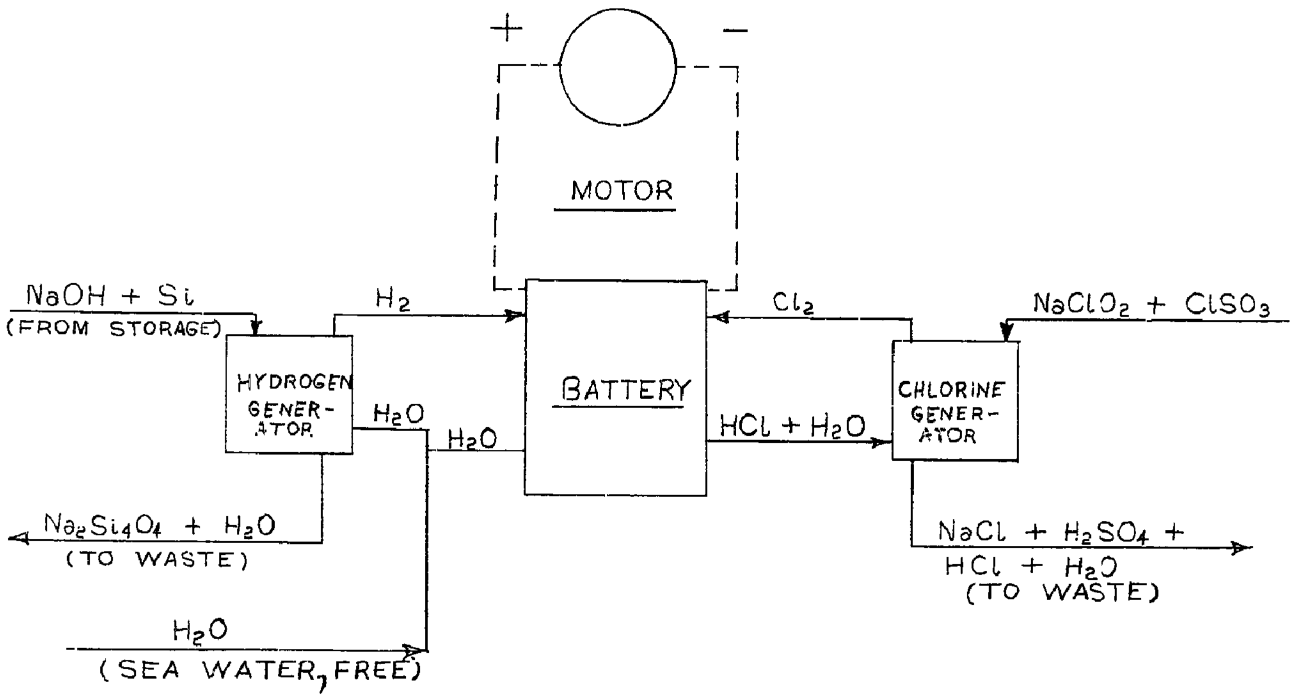

Fig. I-4 Schematic Block Diagram of H_2 - Cl_2 Battery with Gases Generated As Used (Taken from Reference (7)) workable, but it is by no means the only method for developing a fuel cell. There appear to be so many alternates that it is almost certain that a successful fuel cell could be achieved. The major uncertainties are the time requires and the performance obtained.

C. Jet Systems

The advantages of jet-underwater propulsion systems lie in their light weight and their performance at high speeds. In almost every respect they correspond to their airborne counterparts.

1. The Pump Jet

The pump jet, like the jet airplane, is a means for overcoming the decrease in propeller efficiency that occurs at high speeds. It is really a component of a power plant rather than a complete system. A pump, driven by an independent power source, is used in place of a propeller. Water is taken into the missile, accelerated in the pump and nozzle system, and ejected from the torpedo. The difference between the momentum flux of the leaving and entering water results in a net forward thrust exerted on the vehicle. Theoretically, a pump can be designed to give efficiencies of 80 to 85% and to be free of internal cavitation for forward speeds up to and probably exceeding 100 knots. Paper studies have indicated that a 3-inch-diameter, two-stage axial-flow rotor could absorb 200 horsepower at 16,500 rpm and deliver 500 pounds of thrust at a forward speed of 80 knots without undergoing cavitation. A pump jet appears to be one of the methods that can be used efficiently to couple a thermal power plant to a high-speed underwater vehicle. However, there is some evidence[21] that noise is generated at the boundaries of the wake formed by the discharge of the water jet. This phenomenon is imperfectly understood and should be investigated. The true propeller and the high-speed pump jet represent the opposite extremes of mechanisms that can be used for hydrodynamic jet propulsion. An intermediate system, such as the shrouded propeller, may be effective in obtaining increased efficiency and reduced noise at moderate speeds.

2. The Hydroduct

The hydroduct is the waterborne counterpart of the ram jet. The hydroduct consists of an inlet diffuser which admits water into the vehicle. Gas or gas-producing substances (such as lithium) are injected into the low-velocity regions of the diffuser. The gas accelerates the water, and the high-speed gas-water mixture is ejected from a nozzle. The momentum flux difference between inlet and exit streams produces a forward thrust. Like a ram jet, the thrust of the hydroduct is zero at zero forward speed. Consequently, the hydroduct must be brought up to speed by auxiliary means. Although a theoretically attractive high-velocity propulsion system, the hydroduct has not been developed to a stage where it can be evaluated in terms of practical performance. However, it is one of the simplest power plants and might bear scrutiny as the means for the underwater propulsion of a light, cheap antisubmarine weapon. The injection of gas or gas-producing substances into the water could unquestionably be accomplished, but the injection system would be an extra complication. There is a possibility that a simpler device could be constructed in which the water-reactive fuel is placed in the diffuser and the generation of gas allowed to proceed as the water contacts the fuel. This is illustrated in Figure I-[illegible].

3. The Hydropulse

The hydropulse, like the hydroduct, operates on the principle of utilizing the energy of a small amount of expanding gas to accelerate a large mass of water. It is the analogue of the

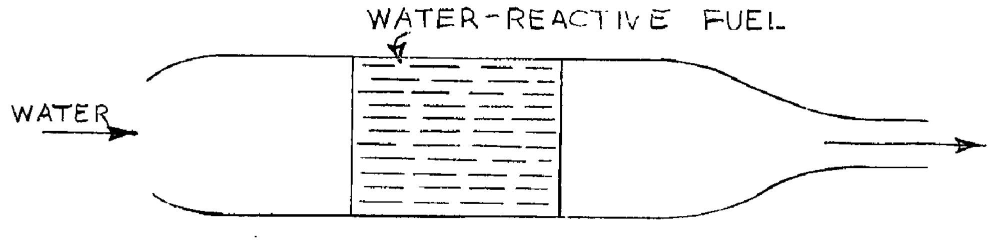

Fig. I-5. Hydroduct

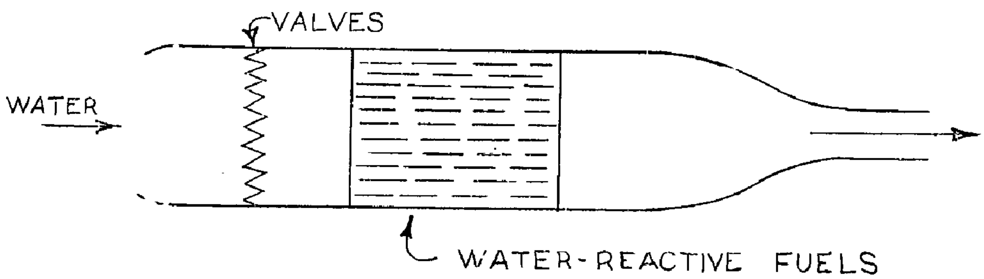

Fig. I-5(a). Hydropulse

pulse jet. The process in the hydroduct is continuous, the process in the hydropulse is intermittent. The duct is filled with water which enters through a valve arrangement. The valve is so designed that it readily opens and allows water to enter from the front so long as the pressure inside the duct is lower than the dynamic pressure of the water. Under all other conditions, the valves are closed. When the duct is filled with water, high-pressure gas or gas-producing fuel is injected; the water is expelled and the process is repeated. The hydropulses that have been tested have taken several forms, but at present the direct hydropulse appears to be the best.

The direct hydropulse obtains its energy from water reactive fuels, such as lithium. The direct hydropulse has been shown to be capable of propelling torpedoes. The hydropulse is a good noisemaker; the noise is in the sonic and ultrasonic frequencies. Experimental tests carried out on a lithium-powered direct hydropulse during 1948 showed that a specific fuel consumption of 3.2 pounds of lithium per thrust horsepower-hour could be obtained at a speed of 40 knots. This was the best value; under other conditions, the consumption increased to values of ten times this magnitude. The hydropulse motor is still in the early stages of development and further work could probably produce a simple, reliable motor with a reasonable fuel consumption.

It may be possible to place the water-reactive fuel in the hydropulse water channel and thus eliminate the feed mechanism. A schematic drawing of this technique is shown in Figure I-9(a). This idea has not been tested.

D. Wake Elimination

Power plants that burn a hydrocarbon fuel with oxygen or hydrogen peroxide are virtually wakeless. Experiments carried out by Arthur D. Little, Inc., under Navy sponsorship showed that proper bubble dispersion eliminated both visible and sonic evidence of the discharge of a 90% CO_2-10% O_2 exhaust gas at depths below 90 feet. If the exhaust gas contains large amounts of oxygen, hydrogen, nitrogen, etc., some wake will result. There is no need to discharge such a gas from a submarine, but torpedo power plants which use water-reactive fuels may discharge considerable quantities of hydrogen. There is little hope of dissolving this hydrogen, and a wake is inevitable is this type of system. The chief application of a hydrogen-generating power plant is in a high-speed torpedo, and wake is not a serious disadvantage. The magnesium-silver chloride battery is an exception to this statement. The chief application of this battery is for low-speed torpedoes ($\sim$30 knots), and at present the side reactions in the battery generate so much hydrogen that a significant wake is visible at moderate depths.

E. Noise Elimination

Compared to the effort devoted to other aspects of underwater propulsion, the problem of noise elimination has received only minor attention. Improvements have been made and preliminary information has been gathered, but a great deal of work still remains to be done before the sources of the noises associated with underwater propulsion systems are quantitatively understood and before the best methods of reducing this noise can be specified. Qualitatively, it is known that, in addition to the internal propulsion machinery noise, external cavitation, occurring on the body and in the propeller slipstream of the torpedo or submarine, is an important source of noise. Generally speaking, both the machinery and the cavitation noise increase in intensity with increase in underwater speed, but at different rates. Roughly, machinery noise seems to be proportional to the sixth power of the underwater speed. This is a surprising empirical finding although it is in moderate agreement with available observational data. Cavitation noise is almost a discontinuous function of the speed. At very low speeds, cavitation noise is a negligible factor; at a critical velocity, it becomes important and increases rapidly with speed, frequently overshadowing the machinery noise. After the sudden jump in intensity over the critical-velocity range, the cavitation noise increases very slowly as the speed is increased. Cavitation noise decreases at increased depth when the speed is fixed, but machinery noise is relatively independent of depth.

With World War II shallow-running torpedoes, machinery noise predominates at speeds up to about 20 knots. In the range of 20 to 40 knots, cavitation noise is more important, and at higher speeds machinery noise again dominates. There is little difference between the noise of present electrically and thermally powered torpedoes; indeed limited data indicate that thermal power plants are quieter. This is based upon comparisons of the noise from the turbine-powered Mk. 13, the battery-powered Mk. 18 and the Ranol reciprocating-engine version of the Mk. 35 and its electrically powered counterpart. Apparently, the electric system suffers from the noise generated in its reduction gears and propellers. With World War II submarines, propeller cavitation noise predominates at speeds above 6 knots and apparently continues to dominate up to their present maximum submerged speeds.

Theoretical studies[21] indicate that propeller cavitation can be eliminated by the use of hydraulic jet-propulsion systems. Development work is needed to confirm the theoretical results and to explore the noise level associated with the jet discharge and machinery. The use of acoustic traps, rubber mounts, etc., might prove fruitful in effecting a reduction in transmitted machinery noise. An attack directed at the noise source within the machinery will require detailed information concerning the generation and propagation of the noise associated with moving mechanisms.

The systems that expel a gas jet appear to emit a significantly greater sound energy spectrum than present submerged power plants. Some exponents of the jet systems feel that this high noise level can be overcome, but definite implementation is lacking.

It is reasonable to suppose that the self-noise of future torpedoes and submarines can be suppressed to levels below those exhibited by present versions, but it will require considerable research and development. Studies of noise and noise reduction are very important. A substantial reduction in noise would not only improve our own weapons but, if discovered by them, would also improve Soviet weapons (see Appendix B, Section VII; Appendix D, Section I). It would be foolish to base detection techniques for U.S.S.R. submarines and torpedoes solely on the results of tests of the noise emanated by present weapons.

III. FUELS

Two main types of fuels have been considered for underwater propulsion -- liquid hydrocarbons and water-reactive metals. In addition, some thought has been given to synthetic fuels such as hydrazine and the metallic hydrides. Hydrazine is not a great deal better than a hydrocarbon as an underwater fuel and is quite toxic. The metallic hydrides are similar to the metals -- reacting with water to form hydrogen. For some applications, they are theoretically superior to the metals themselves, but are more difficult to manufacture and handle.

A. Hydrocarbon Fuels

A hydrocarbon fuel -- typified by "diesel oil" -- is burned with an oxidant in order to generate high temperature-high pressure gas for use in a power plant. The chief advantages of a hydrocarbon fuel lie in the experience accumulated in its handling, storage, and use, as well as its availability and relatively low cost. Sea water displacement may be used to ballast the submerged vehicle. The performance of a hydrocarbon fuel is not so good as a metallic fuel; with the same oxidant, the metallic-fuel consumption per horsepower-hour is about 30% lower than the hydrocarbon fuel.

B. Metallic Fuels

Such metals as lithium, sodium, potassium, calcium, aluminum, and magnesium will react with water to form hydrogen and the metal oxide or hydroxide. This hydrogen can be made to react with an oxidant and used in a thermal or electrochemical power plant. Alternatively, the hydrogen can be generated at a high temperature and pressure and used directly in an expansion engine.

Lithium, sodium, potassium, and calcium undergo spontaneous reactions with water and oxygen. In some respects, this is an advantage, for the generation of hydrogen can be easily accomplished. On the other hand, the extreme reactivity of these elements makes them difficult to handle and potentially hazardous. If stored on board a submarine, a water leak on the storage compartment might lead to a catastrophe.

Aluminum and magnesium react with water and oxygen but, under ordinary conditions, a protective oxide coating is formed which slows the reaction to a standstill. There is comparatively little danger involved in the storage and handling of these materials. At high temperatures (particularly when the metal is molten and small amounts of chlorides are present), magnesium is quite water-reactive. Aluminum is more recalcitrant, and a satisfactory water reaction rate will probably require special techniques.

Lithium and sodium are solids at room temperature, but are easily liquefied (Li melts at 186°C, Na at 97.5°C). When melted, they may be pumped as liquids. Magnesium melts at 650°C and aluminum at 660°C. The melting points of these metals may be lowered by alloying with other metals.

These metals are all made by processes that use large amounts of electric power. Magnesium, aluminum and silicon* were produced in large amounts during the last war. Since then, production has fallen off markedly (in 1946, magnesium production was only 3% of the peak war production rate of 368,000,000 pounds per year). Sodium is a commerical chemical produced in moderate quantities. The large-scale use of any of these metals for submerged propulsion during a war would require additional production facilities unless production were diverted from other essential applications. All these metals would cost in the vicinity of $0.20 per pound.

Potassium and calcium are made in modest amounts for experimental purposes. At present they are relatively expensive. Calcium ores are very abundant, however, and large amounts of calcium probably could be produced at prices near $0.20 per pound; but this would require new facilities.

Lithium production is in a different category. At present, the metal costs about $7.00 per pound. Although lithium ores are reasonably abundant, they are largely low-grade, and the benefication processes are not well developed. Other uses of this metal now have priority over underwater propulsion. Lithium might be made available for torpedoes, but new manufacturing facilities and probably new production techniques would have to be developed.

The reaction of these metals with water produces metal oxides or hydroxides. In most of the proposed propulsion systems, it is not possible to add enough water to dissolve the metallic compounds without encountering a severe loss in efficiency. Consequently, a metal-water "combustion" chamber produces hydrogen and solid or semi-liquid metallic compounds. In the simple jet systems, this two-phase fluid apparently can be tolerated, but the passages of

* Largely as ferro-silicon.

a turbine are coated, and the efficiency of the turbine quickly falls off. A similar situation may hold if reciprocating engines are employed. It is probable that some type of separation system will be needed for any long-time application of the metals for submerged propulsion.

The theoretical performance of the metals in a reciprocating engine similar to the RANOL V-90 torpedo engine is given in Table I-9. The peroxide-diesel oil system performance is also shown. These values are approximate and only indicate the order of magnitude of the performance characteristics. In an actual engine, the consumption (lb./HP-hr.) might be 1.5 times the theoretical values. If used to supply hydrogen to a turbine, the theoretical consumption would be somewhat higher than shown. Limited experimental tests of the use of these metals as hydrogen generators for submerged power plants have been carried out by NOTS (Pasadena)

Table I-9

THEORETICAL PERFORMANCE OF METALS WHEN USED WITH UNSTORED SEA WATER AS HYDROGEN GENERATORS (FOR USE IN A RECIPROCATING ENGINE AT 50 FEET SUBMERGENCE)

Metal	Lb./HP-Hr.	Ft^3/HP-Hr.
Lithium	1.2	0.037
Sodium	5.8	0.096
Potassium	10.0	0.19
Calcium	2.1	0.015
Aluminum	2.4	0.014
Magnesium	2.6	0.025
Diesel Fuel (90% H_2O_2)	2.8	0.037

and Aerojet. Their best results, obtained in short-duration tests, are reported in Table I-10.

Table I-10

BEST EXPERIMENTAL RESULTS OF TESTS OF METALS AS HYDROGEN GENERATORS FOR SUBMERGED POWER PLANTS

Metal	Power Plant	Lb./HP-Hr.	Specific Impulse (Lb./sec-lb.)
Lithium	Turbine	2.3	
Sodium	Turbine	10.7	
Lithium	Rocket Motor		1300
Lithium	Direct Hydropulse	5.2 (thrust HP @ 40.5 knots)	

The previous results apply to systems in which hydrogen gas is discharged overboard. Hydrogen is so difficultly soluble in sea water that a wake is likely at all depths. For fast torpedoes ($\sim$80 knots) the wake is probably immaterial but, for slower weapons, particularly submarines, the hydrogen wake might be intolerable. The wake may be almost completely eliminated if the hydrogen is burned with an oxidant such as oxygen or hydrogen peroxide. This complicates the system and at shallow depths, decreases the efficiency (measured in lb./HP-Hr.) of the system. At extreme depths, the use of an oxidant may improve the power plant since it offers the possibility of the eliminating the effect of depth on the system.

Metallic fuels have considerable promise although a number of problems remain unsolved -- e.g., ballasting, sludging, handling, etc.

IV. OXIDANTS

From a purely logistic standpoint, only three oxidants appear suitable for large-scale use for underwater propulsion -- concentrated hydrogen peroxide, liquid oxygen, and the oxides of nitrogen.

Liquid oxygen is superior in terms of both pounds per horsepower-hour and production cost, but it is more difficult to store and ballast on board the vehicle. Nitrogen oxides and hydrogen peroxide are comparable in terms of pounds per horsepower-hour and storage possibilities. It appears that either of these may be stored between the inner and outer hull of a submarine and ballasted with sea water. Manufacture of nitrogen oxide is considerably cheaper than hydrogen peroxide production, but the oxides of nitrogen are toxic.

A. Hydrogen Peroxide

Hydrogen Peroxide (H_2O_2) is a liquid that can be catalytically or thermally decomposed to produce oxygen gas and water. When used as an oxidant in power plants, it is normally stored as a concentrated aqueous solution containing 80% to 90% by weight of peroxide. A 90% solution of peroxide has a density of 1.3 gm/ml and a freezing point of - 9°C. Although its boiling point is higher, it cannot be safely heated above 160°F since decomposition occurs with the subsequent generation of large volumes of gas. At normal temperatures, 90% peroxide cannot be detonated. Mixtures of peroxide and a fuel, however, are subject to detonation. Peroxide itself attacks the skin, but the products of decomposition are not harmful. If concentrated peroxide contacts organic matter, spontaneous combustion is likely. Catalytic impurities, such as lead, iron, copper, etc., cause the decomposition of peroxide; hence, peroxide storage facilities are subject to sabotage. Uncontaminated peroxide may be stored for long periods (several months) in pure aluminum containers or in plastic bags made of polyethylene or Kel-F. The Buffalo Electrochemical Co. ships 90% peroxide in aluminum drums or tanks via railroad or truck to its customers. Considerable experience has been accumulated both in this country and by the Germans in handling concentrated peroxide, and there is no doubt that it may be shipped and stored if special precautions are observed. For use in a torpedo, peroxide may be stored in an aluminum tank located inside the torpedo or in a plastic bag surrounded by a metal container. The latter procedure is used in the peroxide supply system for the RANOL peroxide torpedo power plant. The peroxide is stored inside the plastic bag which is slipped inside a pressure vessel. The peroxide is fed to the engine by means of sea water which is pumped between the walls of the pressure vessel and the plastic bag. This procedure maintains the original buoyancy of the torpedo. A similar scheme was used by the Germans for the storage of peroxide on board a submarine. The peroxide was stored in plastic bags located outside the pressure hull. As the peroxide was consumed, the bags collapsed, allowing ocean water to enter. In this way, the necessary ballasting of the submarine was accomplished. The plastic used by the Germans for peroxide storage was not completely satisfactory. It was slowly attacked by the peroxide and became brittle. This problem is being studied in the U.S., and it appears that either Kel-F (the chlorine-fluorine-hydrocarbon polymer developed for the Manhattan District) or polyethylene will be satisfactory.

At present, the use of peroxide as the oxidant for hydrocarbons requires the prior decomposition of the peroxide. This is accomplished by the use of catalysts.

A major objection to the use of peroxide as an oxidant is the production cost and the manufacturing facilities involved in its synthesis. In this country, all present peroxide manufacture is based upon the use of an electrochemical process which, in effect, combines atmospheric oxygen with water. This process has several drawbacks:

(1) 9 kilowatt hours of <u>electrical</u> energy are used per pound of 100% peroxide manufactured;

(2) Initial plant investment is high, estimated by the Buffalo Electrochemical Co. at $1.10 per pound per year of 90% peroxide production capacity;

(3) Considerable amounts of platinum and tantalum, items that would be critical in the event of a war, are required.

The Buffalo Electrical Co. is the only commercial producer of 90% peroxide in the U.S. Its production is 5,000 tons of 90% peroxide per year. In addition, the Du Pont Co. operated a Navy-owned plant at Dresden, New York, which has a similar capacity. This production is sufficient to take care of weapon development and testing requirements and, in the event of war, would maintain the torpedoes using peroxide. It would not begin to supply a peroxide-powered submarine fleet.

The electrochemical method is not the only peroxide synthesis technique. During World War II, the Germans were seriously short of electrical power and of platinum and tantalum. Their anticipated peroxide consumption could not be satisfied by new electrochemical plants and they were forced to develop an alternate synthesis. The result was the 2-ethyl anthraquinone process. In this synthesis, 2-ethyl anthraquinone is reduced to the corresponding hydroquinone by the action of hydrogen in the presence of a nickel catalyst. The hydroquinone is then reoxidized by atmospheric air, regenerating the quinone and simultaneously producing hydrogen peroxide. The electric power requirements of this process are small; the hydrogen is generated from coal by means of the water-gas reaction, a technique that has long been employed on a large industrial scale. It is known that the Germans successfully built and operated a pilot plant based on this process and proceeded with the construction of two full-scale plants having a combined capacity of 48,000 tons of 85% peroxide per year. Only one of these plants was completed before the end of the war. Shortly after it commenced operations, an accident occurred which shut it down. The cause of this accident is obscure. In the confusion following the war, all the key personnel of the plant disappeared and our intelligence teams obtained little information. Since a mixture of an organic material and peroxide is alway dangerous, some authorities believe that the accident occurred in the peroxide synthesis or concentration steps. Others, however, report that a fire, started in a benzene storage yard by allied bombing, spread to the main plant. In any event, it is clear that the Germans thought they had developed an alternate synthesis of peroxide that avoided the large electrical consumption and critical material requirements of the electrochemical process, and were willing to build full-scale plants on this basis. Presumably, the initial plant investment is also much lower. There is reason to believe that the difficulties encoountered by the Germans in their first plant could be overcome and that successful full-scale operation of the process could be consummated if further development were carried on. No such program is reported underway in this country, although it is possible that the Buffalo Electrochemical Co. is studying the process in order to estimate its effect on their present production techniques. On the other hand, it is quite possible that the U.S.S.R. has carefully explored the process since they had access to the German peroxide submarine development.

A second possible industrial synthesis of peroxide is the partial oxidation of hydrocarbons. It is known that propane can be oxidized to propylene and hydrogen peroxide by means of oxygen, but the process is still in the laboratory stage. Under Navy auspices, the Shell Chemical Co. and the MIT Peroxide Laboratory are carrying on a limited amount of exploratory work. Potentially, this synthesis is more attractive than the 2-ethylquinone process, since an unsaturated hydrocarbon is a valuable raw material for high-octane gasoline synthesis. It is too early in the program to hazard a guess as to the ultimate success of the method. It is certain that several years' work will be needed before a full-scale plant could be constructed.

At present, the Buffalo Electrochemical Co. sells 90% hydrogen peroxide for $0.60 per pound. Actual out-of-pocket production costs are about $0.17 per pound. The gap represents investment amortization, selling costs, and profit. It is estimated that the 2-ethyl antraquinone process could produce 90% peroxide at an over-all cost (including plant amortization) of $0.20 per pound. This figure is uncertain and should be checked.

B. Liquid Oxygen

Liquid oxygen boils at - 183°C. For this reason, storage of the liquid is a major problem. The evaporation losses inherent in the best storage methods now in use are given in Table I-11. It is reasonable to suppose that these losses can be reduced by further development. For large-scale storage facilities, it is clearly possible to condense the gaseous oxygen by means of a refrigeration system and thus reduce the losses to negligible amounts. A penalty must be paid for this procedure in the form of additional refrigeration equipment and the power and fuel required to run it. This scheme would not be practicable for a torpedo, and it appears that the use of liquid oxygen as a torpedo propellant is limited to missiles that can be fired shortly after they are filled. In addition to reducing the evaporation losses during storage, a reduction in the insulation thickness and an improvement in the structural strength of the container is needed. With present techniques, roughly 25% of the volume and 30% of the weight of the liquid oxygen storage tanks is not usable for oxygen storage. Liquid oxygen tanks are difficult to self-ballast since organic liquids are

Table I-11

LIQUID OXYGEN: EVAPORATION LOSSES

Type of Container	Rated Capacity (pounds)	Evaporation Rates Per Cent/Day of Rated Capacity	Insulation Design
Tank truck	5,000-18,750	10-15% for smaller units to 7-9% for larger	12-15 inches of "Sil-O-Cel" at atmospheric pressure
Railroad tank car	62,000-82,000	1.5 - 2 %	12-15 inches of "Sil-O-Cel" at 0.1 mm Hg
Fixed storage when evaporation rate is of minor importance	10,000-2,000,000	8% for smaller unit to 1% for larger unit	12-36 inches of "Sil-O-Cel" at atmospheric pressure
Fixed storage when evaporation rate is of major importance	20,000-2,000,000	0.4%- 0.5% for smaller size to 0.3%- 0.4% for larger size	12-36 inches of "Sil-O-Cel" at 0.1 mm Hg

Data based on Reference (3)

too hazardous and water would freeze and plug the lines. Perhaps the carbon dioxide in the exhaust gases of an engine could be liquified by counter-current heat exchange with the liquid oxygen and used for ballasting. This problem requires further study. At present, it is proposed to ballast liquid oxygen systems by the use of additional (originally empty) tanks which would be filled with sea water as the oxygen is consumed. Liquid oxygen-fuel mixtures are explosive.

A big advantage of liquid oxygen is the ease with which it can be manufactured. Today, commercial liquid oxygen sells for $0.05 per pound. With large-scale manufacture, this could probably be reduced to $0.03 per pound. Although the present oxygen capacity of the U.S. is very large, it is likely that new plants would be needed in case of war. These plants are quite inexpensive, the original plant investment being estimated at $0.05 per pound of liquid oxygen per year.

C. Oxides of Nitrogen

Such oxides of nitrogen as nitric acid, nitrogen tetroxide, etc., can be used as oxidants. Performance-wise, they are about as satisfactory as hydrogen peroxide. For underwater use they have two major drawbacks: extreme toxicity and a wake problem. The fumes of both nitrogen tetroxide and nitric acid are deadly respiratory poisons. Contamination of a submarine with these materials might be a major catastrophe. Further, the nitrogen released by their reduction is difficult to disperse without creating a wake. For these reasons, it is doubtful if the U.S. Navy would be willing to adopt them for use as oxidants for submarine propulsion. They might, however, be used for torpedo propulsion.

Nitrogen oxides are comparatively easy to manufacture. Nitric acid is an essential raw material for explosive synthesis, and nitrogen tetroxide can be made by minor modification of nitric acid plants. In addition, the Food Machinery Corp. has developed a new process that is considerably cheaper than the present ammonia oxidation technique. The extensive use of nitrogen-base propellants would require new nitrogen-fixation facilities. It is estimated that the Food Machinery Corp. process could produce nitrogen tetroxide at a cost of \$0.03 per pound and with a plant investment of \$0.03 per pound per year of production capacity.

The oxides of nitrogen could be stored on board a submarine, and it appears that the storage tanks could be ballasted with sea water by use of a suitable movable-diaphragm technique. A nation that is willing to risk the hazards of these materials might find the use of the oxides of nitrogen a relatively cheap and easy way to supply oxidant to a submarine power plant.

D. Esoteric Oxidants

A number of esoteric oxidants -- ozone, fluorine, chlorine trifluoride, etc. -- have been considered for rocket propulsion. In theory, they could also be applied to underwater propulsion. If they could be used, they would be superior to liquid oxygen. At present, however, all these compounds are either too unstable, too expensive, or both, for use underwater. At some future date they may prove suitable.

E. Oxidant Replenishment

The chief drawback of the chemically fueled submarine is the limited oxidant supply that can be stored on board. Two ways of improving this situation have been suggested -- obtain oxygen from the air or from the sea. The replenishment of stored oxygen by the use of atmospheric air implies the manufacture of oxygen during periodic surface or snorkel operation.

The use of the oxygen in the sea water might mean a continuous supply of oxygen for submerged propulsion. A straightforward engineering attack on the problem of periodic replenishment with atmospheric oxygen would be to put a liquid oxygen system on board a submarine. This may be possible, but the machinery is likely to be bulky and the weight of fuel consumed by the plant is likely to be a significant fraction of the weight of oxygen produced.

An alternate to the liquid oxygen plant is a scheme that visualizes an engineering adaptation and combination of the respiratory mechanism of both mammals and fish. If it could be made to work well, it would bring the performance of the chemical power plant close to that of the nuclear plant. It is probable that such a system is impracticable. On the other hand, a preliminary exploration designed to clearly define the problem, to obtain basic data, and to assay the probability of success could probably be completed in less than two years and at a modest cost. Even though the chance of success appears slim, the potential rewards might justify such an examination.

V. CONCLUSIONS

A. Torpedoes

1. U. S. Systems

Table I-12 summarizes the characteristics of representative U. S. torpedo power plant fuel-oxidant systems now in use, ready for use shortly, and estimates of what might be obtained with up to 10 years of intensive development. All possible systems are not included, and the compilation cannot be considered comprehensive. The estimates of the specific performance of future developments are subject to error. This is particularly true of the jet systems. The specific weight (lb./HP) and volume (vol./HP) of the jet power plants will be lower than that of the electric or thermal systems, but the estimates of the obtainable values have varied so widely that no figures are reported here.

Certain qualitative conclusions can be drawn on the basis of Table I-12.

TABLE I-12 REPRESENTATIVE TORPEDO POWER PLANTS

Power Plant	Wt. Power Plant (lb./SHP) Surface	Wt. Power Plant (lb./SHP) 1000 ft.	Vol. Power Plant (ft^3/SHP) Surface	Vol. Power Plant (ft^3/SHP) 1000 ft.	Stored Expendables Fuel	Stored Expendables Oxidant	Wt. of Expend. (lb./HP/hr.) Surface	Wt. of Expend. (lb./HP/hr.) 1000 ft.	Vol. of Expend. (ft^3/HP/hr.) Surface	Vol. of Expend. (ft^3/HP/hr.) 1000 ft.	Comments
NOW IN OPERATIONAL USE											
(1) Electric	15.5[a]	---	---	---	Lead-H_2SO_4	Stor.Batt.	200	---	---	---	Mk 18 - 29 knots to 4000 yds.
(2) Turbine	0.75	---	---	---	Alcohol	Air	18	---	0.80	---	Mk 14 - 45 knots to 4500 yds.
SUBSTANTIALLY READY FOR OPERATIONAL USE											
(3) Electric	8.5[a]	8.5[a]	0.12[b]	0.12[b]	Mg-AgCl-H_2O	Prim.Cell	20	20	0.5	0.5	Mk 35 - 27 knots to 10,000 yds.
(4) Turbine	1.0	---	0.011[c]	---	Alcohol-48 H_2O_2		14.3	---	0.8	---	Mk 16 - 46 knots to 11,000 yds.
READY FOR PRODUCTION WITHIN ONE YEAR											
(5) Reciprocating	0.8[d]	1.2	0.008	0.013	Diesel	85 H_2O_2	5.5	11	0.07	0.14	RANOL V-90 for Mk 41 or 35, substantially wakeless
READY FOR PRODUCTION WITHIN THREE YEARS WITH INTENSIVE EFFORT											
(6) Thermal	0.6	0.9	0.005	0.0075	Diesel	90 H_2O_2	3.8	7.0	0.05	0.09	Substantially wakeless
(7) Thermal	0.6	0.9	0.005	0.0075	Lithium	---	2.0	4.6	0.07	0.12	Hydrogen wake
READY FOR PRODUCTION WITHIN TEN YEARS WITH INTENSIVE EFFORT											
(8) Thermal	0.5	0.5	0.006	0.006	Li+Ca,Mg or Al	90 H_2O_2	2.5	2.5	0.03	0.03	Wakeless, high-speed pump-jet
(9) Electric	5.0[a]	5.0[a]	0.04[b]	0.04[b]		Primary Cell	10	10	0.07	0.07	Projection of semi-package cell development
(10) Hydropulse[e]					Li+Ca,Mg or Al	---	5.5	10 (?)	0.07	0.14 (?)	Simple, cheap, possibly noisy, hydrogen wake
(11) Rocket[e] (Hydroturbojet)					Li+Ca,Mg or Al		10	20 (?)	0.12	0.24 (?)	Reasonably simple, possibly noisy, hydrogen wake

(a) Weight of battery, motor, and accessories
(b) Volume of battery, motor, and accessories
(c) Includes reducing gear; turbine alone = 0.005 ft^3/SHP
(d) Does not include controls and pumps
(e) Specific performance figures are very uncertain estimates

1. The battery-electric motor systems (Table I-12, rows 1, 3 and 9) are characterized by a high weight and volume per horsepower and per horsepower-hour. This implies a relatively low speed and a moderate range.

2. The pure jet systems (Table I-12, rows 10 and 11) obtain low weight and volume per horsepower at the cost of fuel consumption. Their chief use appears to be for high speed-short range or for moderate speed-moderate range applications.

3. The thermal systems (reciprocating or turbine power plants) of Table I-12 (rows 2, 4, 5, 6, 7 and 8) provide the combination of moderate volume and weight per horsepower and low fuel consumption. They appear best adapted to moderate to long-range operation at either moderate or high speeds since, under these conditions, the weight and volume of fuel are more important than the size and weight of the power plant.

In order to provide a more concrete estimate of the performance of these power plants, the data of Table I-12 have been used to calculate roughly the performance that might be obtained in a Mk. 35-class torpedo. The results, which are quite approximate, are shown in Table I-13. Rows 1, 2 and 3 represent stages in the development of the electric torpedo. Row 1 shows the performance of the present Mk. 35 torpedo powered with the magnesium-sea water-silver chloride cell. Row 2 is an estimate of what might be obtained by improving the sea water cell. Row 3 is based upon a guess as to the probable progress that might be made in package-cell construction in 10 years. In order to obtain speeds greater than 40 knots with batteries, it would be necessary to lengthen the torpedo; speeds about 60 knots appear to require impractical torpedo lengths.

Table I-13

ESTIMATED PERFORMANCE SOME OF THE POWER PLANTS OF TABLE I-12 INSTALLED IN MK. 35-TYPE TORPEDO (approx. 1700 lb. dry weight)*

	Power Plant	Max. Speed (knots)	Range (yards) 50-foot depth	Range (yards) 1000-foot depth	Stored Fuel	Stored Oxidant	Estimated Earliest Production Date if Actively Prosecuted
1	Electric	27	10,000	10,000	Mg-AgCl	cell	1950
2	Electric	33	10,000	10,000	Mg-AgCl	cell	1952
3	Electric	40	25,000	25,000	?	?	1960
4	Thermal	30	30,000	15,000	Hydro-carbon	H_2O_2	1951
5	Thermal	35	30,000	15,000	Hydro-carbon	H_2O_2	1952
6	Thermal	60	6,000	4,000	Hydro-carbon	H_2O_2	1954
7	Thermal	40	30,000	30,000	Li-Ca**	H_2O_2	1957
8	Thermal	60	10,000	10,000	Li-Ca**	H_2O_2	1957

* In general, a smaller torpedo will have a shorter range or slower speed; a larger version a greater range or higher speed than one the size of a Mk. 35

** This assumes that lithium can be made available; if not, another water-reactive metal would be substituted with some loss in performance

Rows 4, 5 and 6 represent stages in the development of the hydrocarbon fuel-hydrogen peroxide power plant. Row 4 shows the performance obtained during the development testing of the RANOL V-90 reciprocating engine power plant. Row 5 is a translation of probable short-time improvements in the performance of the thermal peroxide power plant into torpedo performance. Row 6 is a high-speed version of the hydrocarbon fuel-hydrogen peroxide-powered thermal system. A new engine (either a reciprocating engine or a turbine) and improved stowage would be needed.

Rows 7 and 8 are estimates of the performance of a thermal power plant combined with several modifications that are still in the laboratory stage. The basic power plant is a reciprocating engine or a turbine. The oxidant is 90% hydrogen peroxide. The fuel is a water-reactive metal (considered here to be Li-Ca). This fuel is reacted with excess sea water, and a high-pressure hydrogen-steam mixture is generated. The metallic sludge is separated from the gas (probably by a cyclone separator), and the gas mixture burned with the peroxide. The expansion of the gases generates power in a reciprocating engine or turbine. The power is used to run a pump jet. The exhaust gases are almost entirely water vapor; they are condensed with sea water, and the liquid and very-small fraction of gas is pumped overboard. This virtually eliminates the effect of operating depth on power-plant performance. Such a system is a long way from reality. In theory, it is close to the ultimate in thermal propulsion systems for deep-running torpedoes, but it will require a real effort to accomplish the results indicated in Table I-13.

In Table I-13, the Mk. 35-class torpedo was used as an illustration. This does not imply that the size of the present Mk. 35 is ideal. For airborne use, a much smaller weapon is desirable. The data of Table I-12 indicate that our present power plants would be suitable for use in a small torpedo. For example, the thermal power plant using a hydrocarbon fuel and hydrogen peroxide appears to be sufficiently developed for use in a 500-pound, 30-knot, 4,000-yard-range torpedo. An even smaller weapon could be built at some sacrifice in speed or range. If extremely high speeds are needed, one of the jet systems might be used in a small, short-range weapon. High speeds for very-short ranges might be obtained with air-launched chemical rockets whose power plants continued to function under water. With present know-how, the U.S. could build a large torpedo (3,000 pounds) with a speed of 50 knots and a range of 30,000 yards.

If hydrogen peroxide is used as an oxidant, the wake of the thermal power plants of Table I-13 would be negligible. Presumably, the wake of the present magnesium-silver chloride battery can be eliminated by further work, and future batteries will be wakeless. The jet systems employ hydrogen (generated by the reaction of fuel with water) and would exhibit a pronounced wake.

The gas-jet power plant systems would probably be noisy, but this has not been conclusively demonstrated. At present, the noise of the 30-knot Mk. 35 torpedo, powered with either the electric or thermal (RANOL engine) system, is almost entirely due to propeller cavitation. The use of a non-cavitating pump jet instead of a conventional propeller might considerably reduce the noise level of the torpedo and make a 40-knot thermal-or electric-powered acoustic torpedo possible. Little effort has been expended on sound isolation of the machinery.

The production of a truly high-speed acoustic torpedo will require far greater emphasis on noise reduction than is presently the case.

2. U.S.S.R. Developments

The progress made by the U.S.S.R. in torpedo development is not known. At the close of the last war, the Germans were testing torpedoes that used hydrogen peroxide as an oxidant. The German information and prototype torpedoes were available to the U.S.S.R. Presumably the Soviets have continued the German work and added improvements of their own. It is reasonable to assume that their weapons will be capable of long range at moderate to high speeds and will be fitted with homing and pattern-running devices.

B. Submarines

1. U.S. Developments

Table I-14 lists the estimated performance of seagoing submarines of 2,000 to 3,000 tons submerged displacement as a function of the power plant employed. This Table includes the estimated date at which production might begin if the development effort were started now, and the cost of the fuel and oxidant consumed per patrol. The oxidant costs are taken to be $60.00 per ton for liquid oxygen and $400.00 per ton for 90% hydrogen peroxide. Both these figures are lower than present selling prices in the U.S. However, the production of sufficient additional quantities of either of these oxidants for a reasonable number of submarines would require new plant facilities. A large modern plant should be able to manufacture liquid oxygen for $60 per ton. The hydrogen peroxide cost is based on the estimated* economics of the 2-ethyl anthraquinone process developed by the Germans. The conventional electrolytic process now used in the United States is not able to produce peroxide for $400 per ton. Presumably the U.S.S.R. has acquired the German background in peroxide manufacture, the U.S. would need to develop either the 2-ethyl anthraquinone process or the propane oxidation process to meet the $400-per-ton figure.

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* An uncertain estimate.

ADDENDUM

to Table I-14

In Table I-14, the maximum snorkel speeds given assume that all the thermal power plants are operated during snorkeling. The U. S. Navy does not feel that it is practicable to install exhaust connections to more than two of the four diesel engines in a conversion of a Fleet to a Guppy-type submarine. With this limitation, the snorkel speed of the submarines of Columns 2, 3, 4, 7, and 8 of Table I-14 would be restricted to about 12 knots.

Table I-14

ESTIMATED PERFORMANCE OF SEA-GOING SUBMARINES

	1 FLEET	2 GUPPY	3 GUPPY Conv.A	4 GUPPY Conv.B	5 SS563	6 SS563 Mod.	7 GUPPY Conv.C	8 GUPPY Conv.D	9 SSX	10 SSN (nuclear)	11 FUEL CELL
Estimated Date at Which Production Might Begin	1950	1950	1952	1952	1952	1955?	1955	1955	1955	1955	1960
Estimated Cost millions of dollars*		2.1	3 ?	4.3?	12	16?	4.5?	3 ?	19		19?
Maximum Submerged Speed (knots)**	10	14.5	12	14.5	18	18	18	14.5	25	25	25
Range at Max. Sub. Speed (miles)**	11.3	16.5	100	16.5	20	53	346	16.5	250	15,000	850
Maximum Submerged Horsepower	3000	4600	3000	4600	4700	4700	10,000	4600	15,000	15,000	15,000
Range Submerged at 6 Knots (miles)**	40	145	450	130	220	600	3100	3000	4350	40,000	14,000
Range Submerged at 6 Knots on Storage Batteries Only, (miles)	40	145	72	72	220	600	---	145	145	---	---
Maximum Surface Speed (knots)	21	20	15	20	15.5	15.5	20	19	22	22	22
Maximum Surface Horsepower	5400	5400	4000	5400	3200	3200	5400	4800	15,000	15,000	15,000
Maximum Snorkel Speed (knots)	---	18.5	14	18.5	14	14	18.5	17.5	20	---	20
Range on Surface at 10 Knots (miles)	12,000	10,000	10,000	10,000	12,500	12,500	10,000	10,000	14,000	43,000	14,000
Submerged Displacement (tons)	2428	2428	2428	2428	2170	2170	2428	2428	3000	3000	3000
Weight Machinery (tons)	130	130	130	130	160	160	230	130	400	840	250
Weight Storage Batteries (tons)	210	252	126	126	255	202	50	250	126	---	---
Weight Diesel Fuel (tons)	203	203	215	203	200?	200?	240	240	430	---	375
Weight Stored Oxidant as Either Liquid Oxyg. (tons)	---	---	25	---	---	---	---	---	150		
or 90% Hydrogen Peroxide (tons)	---	---	75	---	---	---	300	175	250		
Weight Special Fuel (tons)	---	---	---	50	---	---	---				450
Cost of Fuel Per Patrol (thousands of dollars) For											
Diesel Fuel at $31/ton	6	6		6	6						
Diesel Fuel - Liq. O_2 at $60/ton			8.2						22		
Diesel Fuel - 90% H_2O_2 at $400/ton			36				130	77	110		
Primary Batteries at $22,500/ton				2200							
Diesel and Special at $400/ton											200

* For Columns (2), (3), (4), (7), (8) the conversion cost from a Fleet Submarine is given

** Speed-range characteristics of thermal powerplants may be roughly interpolated by considering the range to vary inversely with the square of the speed

The performance of the nuclear-powered submarine (SSN, column 9 of Table I-14) now under development in the U.S. is included in the Table in order to compare the chemical and nuclear submarines. A chemical system that might offer performance comparable to the nuclear submarine has been omitted from the Table because the practicability of this system cannot be evaluated at the present time. (This is a system that continually replenishes its oxidant supply by extraction of oxygen from the air and from the sea water and, although improbable, might give continuous high-speed submerged operation.)

Additional data of Table I-14 are summarized below.

1. <u>The Fleet Submarine</u> (column 1):- This is the U. S. World War II fleet submarine. It uses diesel engines for surface operation and a combination of electric motors-lead storage cells for submerged propulsion. It is not snorkel-equipped, although a snorkel can be added.

2. <u>The Guppy Submarine</u> (column 2):- This is a modification of the fleet submarine. The hull is streamlined (cost $350,000), a snorkel is provided (cost $450,000), and improved lead storage batteries (the "Guppy" battery) are installed (cost $1,345,000).(5)

3. <u>Guppy Conversion A</u> (column 3):- This is a version of the Guppy submarine which converts the Guppy diesel engines into submerged power plants. The modification involves removing one-half the usual Guppy storage batteries and substituting liquid oxygen or hydrogen peroxide storage tanks. Two of the main 1,600-HP diesel engines would also be removed. They would be replaced by two 500-HP diesels and the pumps, condensers, etc., required to convert the remaining diesels to simple Kreislauf operation. The U. S. Navy Bureau of Ships has tested the components required for

this conversion and has made paper studies of the installation. It believes the conversion to be feasible, but does not contemplate carrying out the modifications.

4. Guppy Conversion B (column 4):- This is a hypothetical modification of the present Guppy. One-half the normal lead storage batteries are replaced by magnesium-sea water-silver chloride primary batteries. This conversion appears impracticable. No significant performance improvement results and, since the primary cells must be replaced after each patrol, the cost would be enormous.

5. SS 563 (column 5):- This is a new model of the conventionally powered fleet submarine. A prototype is now under construction. It is diesel engine-powered on the surface and uses a combination of electric motors and lead storage batteries for submerged operation. Larger versions of this submarine have been studied on paper. An 11,000-ton submerged displacement model might be built with a maximum submerged speed of 30 knots and a range of 34 miles at 30 knots.

6. SS 563 Modification (column 6):- This is a hypothetical modification of the SS 563. The lead storage batteries are replaced with an equivalent volume of the zinc-sodium hydroxide-silver oxide ("Yardney") storage cells. This modification assumes that the best performance of the present experimental models of the Yardney cell could be duplicated in a production version. There is no assurance that this could be achieved.

7. Guppy Conversion C (column 7):- This is a hypothetical conversion of the Guppy to a high-submerged-speed submarine. The four diesel engines are modified for Kreislauf operation, and four small-size but high-power (approximately

1,000 HP each) upstream expansion engines (either reciprocating or turbine) are added. A small engine of about 400 HP is added in order to obtain high efficiency at speeds of 6 knots and lower. This engine would be made as quiet as possible. The space and weight for the additional machinery is provided by removing batteries. Additional storage capacity is obtained by sacrificing one-third of the normal 600 tons of ballast; this would reduce the loaded freeboard of the submarine but does not appear to unduly restrict its operation. Peroxide is chosen as the oxidant because it can be stored between the inner and outer hull and ballasted with sea water. Possibly a scheme involving liquid oxygen could be worked out.

8. Guppy Conversion D (column 8):- This is a hypothetical conversion of the Guppy to an extreme-submerged-range submarine. The storage batteries are retained in order to provide a means of obtaining rechargeable high-speed, short-time submerged operation. A 3,000-mile totally submerged range at 6 knots, suitable for sneaking through patroled areas, is obtained by the use of stored oxidant. This is achieved by removing one diesel engine and replacing it with a 400-HP modern thermal plant. This thermal plant can use air or stored oxidant and can operate efficiently at depth. Every effort is made to eliminate the noise of this small engine. Hydrogen peroxide is stored outside the pressure hull at the sacrifice of ballast. The remaining diesels are not changed. When long-range submerged cruising is desired, only the 400-HP plant is operated. When high submerged speeds are needed, the storage batteries are used.

9. Submarine SSK (column 9):- This is a new chemically powered submarine which is being studied by the U.S. Navy. The entire submarine is now in the preliminary design

stage, but the power plant is close to actual testing. The target specifications of the Walter cycle, semi-closed gas turbine, and closed-cycle gas turbine submerged power plant developments call for the final unit to fulfill the requirements of the SSX. It is expected that, by 1952, the testing of experimental versions of these power plants will have reached the stage where one of them can be selected for the SSX. The final status of the SSX development has not been decided.

10. The Nuclear-Powered Submarine SSN (column 10):- Alternate power plants for this submarine are under development at the General Electric Co. and the Westinghouse Electric Co. It is hoped that an experimental version of this submarine will be under test by 1955.

11. The Fuel-Cell Version of the SSX (column 11):- This is a purely conjectural modification which substitutes a fuel cell-electric motor combination for the storage batteries and the thermal underwater power plant of the SSX. The performance given in Table I-14 for this system is based upon the estimate given in Table I-7 of what might be achieved as the result of a ten-year fuel-cell development. Clearly, this is a guess; the performance listed might never be achieved, or it might be greatly surpassed.

At depths below 100 feet, the exhaust gas wake of these submarines would be negligible if the bubble dispersion exhaust system were employed. At high underwater speeds, the propeller and probably the machinery noise would be pronounced. The development of a pump jet for submarines has a low priority at the present time, and little attention has been given to machinery-noise isolation. Considerable effort in both basic research and development will be required to achieve a quiet high-speed submarine, but such an objective does not seem impossible. This could have an important effect on sound-detection methods.

2. U.S.S.R. Developments

Potential Soviet developments in submarine propulsion parallel those of the U.S. At the close of the war, the German developments fell into Soviet hands; these included the Type XXI boats whose performance is close to that of the Guppy class, and the experimental hydrogen peroxide (Walter) and oxygen (Kreislauf) powered submarines. Presumably the U.S.S.R. has carried on these developments, aided by German scientists and engineers.

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APPENDIX K

I. HARTWELL PROJECT: HISTORY AND SOURCES

The instigation of the Hartwell Project dates from a letter* from the Committee on Undersea Warfare of the National Research Council addressed to Admiral C. B. Momsen, Assistant Chief of Naval Operations. This letter recommended in part the determination of a long-range program against submarines taken in its broadest sense to include (a) transport and cargo handling, (b) vehicle and weapon systems, and (c) submarine defense. To help define such a program, the Committee on Undersea Warfare suggested enlisting the assistance of a group of "outstanding personnel providing a high degree of technical, scientific, and operational competence under the most skilled and vigorous leadership".

In following up the recommendations, Admiral Momsen with Admiral Solberg, Chief of the Office of Naval Research, conferred in New York on February 27, 1950, with Dr. M. J. Kelly, Director of Research, Bell Telephone Laboratories.** Present also were Dr. J. B Fisk, assisting Dr. Kelly at Bell Telephone Laboratories, and Dr. J. A. Stratton, Provost of the Massachusetts Institute of Technology. At this meeting, it was pointed out by Dr. Stratton that M.I.T. would cooperate with the Navy if the Navy felt that the advanced-type submarine presents such a critical national problem. It was the opinion of the civilian scientists present that Dr. J. R. Zacharias might be well fitted to direct a group of scientists to study the long-range aspects of anti-submarine warfare.

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* G. P. Harnwell, Deputy Chairman to Admiral C. B. Momsen, ACNO (Undersea Warfare), Jan. 23, 1950.

** Memorandum from Admiral C. B Momsen to Admiral F. P. Sherman, CNO, February 28, 1950.

Adm... ... [illegible]

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willingness of M... [illegible]

"Pr... [illegible]

J. R. Zacharias w... [illegible]

This letter also outlined [illegible]

of operation, and discussed classi... [illegible]

In stating the objective, Mr. Killian pointed out [illegible] a group would desire in no way to duplicate any evaluation of current methods and plans already undertaken by [illegible] the Navy, but would explore possibilities of new methods and their potentialities and to emphasize salient features of old ones.

The method of attack would be to utilize a small, highly skilled group, which [illegible]. The plan of operation suggested a June briefing [illegible] of intensive study to extend from June 1 to Aug... [illegible]

Subsequent to receipt of this proposal [illegible] Momsen and Admiral T. A. Solberg visited M.I.T. [illegible] to discuss the proposed project [illegible]

At this meeting with Dr. Stratt... [illegible] "Method of Attack," and "Plan of Operation" were [illegible] tentative schedule was established: briefing [illegible] include Key West and New London; work [illegible] to be followed by a review August [illegible]

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* J. R Killian, Jr., to Admiral F. P. Sherman, CNO, Mar... [illegible]

** See Memorandum, T.A. Solberg to Admiral Sherman, A... [illegible] arranged that a contract covering this work would be negotiated by ONR with M.I.T. At the same time, the name "Hartwell" was confirmed; the code name and classification of the contract would be Restricted. Reports, however, would carry the classification of the material contained therein. At this meeting it was agreed that ONR would assign Commander W. H. Groverman, in charge of the Undersea Warfare Branch, ONR, to act as project liaison officer and to arrange details of the briefing.

While the contract was being arranged through normal channels (first approval by RDB, then negotiation with the Division of Industrial Cooperation, M.I.T.) a preliminary meeting was held in Washington at the National Academy of Sciences Building on April 27 during the Washington meetings of the American Physical Society. At this time, a large number of scientists potentially useful to the project were at hand in Washington and many were able to attend the meeting.

The meeting* was attended by twenty-two scientists and seven Navy representatives from CNO and ONR. Professor Zacharias presided.

A program and a tentative schedule of briefing had been prepared by Commander Groverman, copies of which were distributed at this meeting. The program included the following items for discussion:

(1) Nature of the project;
(2) Dates;
(3) Briefing;
(4) Personnel;
(5) Classification and Security;
(6) Reviewing Group;
(7) Report.

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* See Memorandum, M. M. Hubbard to J. R Zacharias, May 2, 1950.

The nature of the project was described by Admiral Solberg, ONR, who summarized the steps leading to the Hartwell Project and listed the difficulties in the problem. He also described and applauded the previous contributions and operations of the Underseas Warfare Committee. He pointed out that the Navy, in the Hartwell Project, was seeking new approaches. The Admiral reassured the meeting that the Navy was backing the project to the hilt.

General discussion followed on the nature and scope of the project. In this discussion, many participated. It was stressed that the problem is broader than simply the "detection of submarines" or even the "detection and killing of submarines", covering, indeed, the problem of overseas transport and the protection of fast carrier task forces. It was made clear also that this project is not simply an evaluation group; the Navy looks to it for guidance on future long-range plans; its results can be used to initiate new programs, new groups. The item of dates provoked no discussion. The briefing procedure was then explained by Commander Groverman. The tentative schedule was:

Washington	1 week, beginning June 5;
Key West	1 week (including one day observing a problem at sea);
New London	ending June 23.

There was little discussion of this schedule, which became the final program with only slight modifications. It was suggested that the group seek the advice of Admiral Low during the briefing, which was done.

In regard to personnel, it was pointed out that the group present was representative of those selected. It was expected that not too many additions would be made to the senior staff, but suggestions for additional names were invited, both for senior staff and for assistants.

The classification of the project was defined by Groverman who explained that the contract itself is "Restricted". The work and reports must bear the classification appropriate to the matter in them. If a "Secret" matter is investigated, the report must itself be "Secret". The project personnel would be processed for clearance to "Top Secret" information.

In the Fall, a reviewing group might be assembled to view and comment on the work of the project; names suggested for this included L. A. DuBridge and M. J. Kelly. Such a group would be asked to punch holes in the conclusions of the Hartwell Group.

In regard to reports, little was said, except that the final conclusions might not appear in an elegant format since time was so short.

At this same meeting, announcement was made of the forthcoming Symposium of the Committee on Undersea Warfare to be held May 15 and 16. The Hartwell Group as then constituted was invited to attend. (Several members of the Hartwell Group did attend the symposium.)

The Hartwell Briefing* began on June 5 at the Pentagon. The group, for the most part, stayed at the Hotel Washington. Discussion sessions were held there every evening to amplify and supplement material presented at the formal presentations. The evening sessions were frequently attended by persons who had delivered papers during the day. During the evening, they expanded their discussions. These evening sessions were so fruitful that the practice was continued when the group reached Key West and New London.

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* See program of briefing, Section II.

II. BRIEFING OF HARTWELL GROUP

A. WASHINGTON

Pentagon Building   Room 4-E-442

Monday, June 5

Speaker and Agency	Subject
Vice Admiral L. D. McCormick, Vice Chief of Naval Operations, CNO	Introduction
Vice Admiral F. S. Low, Deputy Chief of Naval Operations (Logistics), Op-04	Low Board Report
Cdr. E. Haskins, Op-32	Intelligence Estimate
Lt. Cdr. M. R. Wyatt, Op-32	Intelligence Estimate
Cat. G. Conway, NSRB	Shipping Control Requirements
Capt. Hunt, Op-40	Requirements
Capt. Knowles, CIA	Requirements

Tuesday, June 6

Dr. J. Steinhardt, OEG	Overseas Transportation
Rear Admiral C. B. Momsen, ACNO (Undersea Warfare), Op-31	Tactical Aspects
Capt. C. T. Caulfield, Op-312	Surface Aspects
Capt. L. R. Daspit, Op-311	Submarine Aspects
Capt. T. Burrowes, Op-314	Harbor Defense

Wednesday, June 7

Capt. R. G. Armstrong, Op-314	Mines and Countermeasures
Dr. E. A. Johnson, ORO	Mines and Hydrofoils
Dr. J. W. Johnson, ORO	Mines
Dr. G. H. Shortley, ORO	Hydrofoils
Dr. J. B. Hersey, Woods Hole	Environment
Cdr. S. H. Gimber, BuShips	BuShips Program

Thursday, June 8

Rear Admiral C. M. Bolster, BuAer	BuAer Program
Capt. L. D. Coates, Jr., BuAer	" "
LCdr. E. W. Harrison, BuAer	" "
Capt. W. S. Whiteside, BuOrd	BuOrd Program
Cdr. W. H. Groverman, ONR	ONR Program
Dr. G. P. Harnwell, Com. USW	Program of Committee on Undersea Warfare

At Hotel Washington

Mr. J. H. Alberti, Op-322	Intelligence
Rear Admiral L. G. Stevens, JCS	Intelligence
Cdr. J. F. Dalton, NCS	HF/DF
Cdr. D. F. Quackenbush, NCS	HF/DF
Cdr. S. Bertolet, NCS	HF/DF
Mr. J. J. Cummings, NCS	HF/DF

At Naval Research Laboratory

Friday, June 9

Capt. F. R. Furth	Introduction
Mr. H. O. Lorenzen	Use of Countermeasures in Anti-Submarine Warfare
Dr. H. L. Saxton	Knowns and Unknowns in the Detection of Submarines by Sonar
Dr. J. A. Sanderson	Infrared and Exhaust-Trail Detection of Submarines
Mr. M. Katzin	Radar Detection of Schnorkeling Submarines
Dr. R. M. Page	Some Possible Systems for Detection of Schnorkel by Radar

B. KEY WEST

Monday, June 12

Commanding Officer, Fleet Sonar School Commanding Officer, SurAsDevDet Commander, Submarine Squadron FOUR Commanding Officer, Air Development Squadron ONE Officer in Charge, Advanced Undersea Weapons School Officer in Charge, Naval Ordnance Unit	Briefing Conference
Captain Caruthers, Fleet Sonar School	

Tuesday, June 13

Captain C. E. Weakley	Surface Anti-Submarine Development Detachment(1),(2)
Cdr. L. V. Julihn, AUW	Torpedoes

Wednesday, June 14

Captain E. C. Stephan, Submarine Squadron FOUR	Briefing for ASW Demonstration

Thursday, June 15

Observation of ASW Demonstration (3), (4)

Friday, June 16

Cdr. V. E. Schumacher	Naval Ordnance Unit

OpDevSta -- ASW Critique

(1) Memorandum for Surface Anti-Submarine Development Detachment, Key West, Florida, June 12, 1950, "SurAsDevDet and OpDevSta".

(2) Current Projects at SurAsDevDet, June 12, 1950.

(3) Memorandum from Commanding Officer, Surface Anti-Submarine Development Detachment, to Observers of Operation VISITING FIREMEN, "Information for Demonstration of 15 June 1950, dtd. 12 June 1950.

(4) "Description of Operation 'VISITING FIREMEN,'" 15 June 1950, Surface Anti-Submarine Development Detachment, Key West, Florida.

C. NEW LONDON

At ComSubLant

Monday, June 19

Rear Admiral S. S. Murray	Introductory Remarks
Captain J. F. Davidson	Tactics and Operational Characteristics of the Fleet-Type Submarine
Captain C. O. Triebel	Tactics and Operational Characteristics of the Guppy-Snorkel Submarine
Captain C. H. Andrews	The Characteristics of the 1955 Submarine
Captain Benson	The Submarine as an ASW Weapon

Tuesday, June 20

Cdr. E. E. Shelby	The Operations and Limitations of the Submarine as a Mine Layer
Cdr. W. B. Sieglaff	Coordinated Submarine Tactics
Captain J. Corbus	Wartime Operation Cycles -- Operations Involved in Performing Secondary Missions
Captain W. G. Ebert	Submarine Operations in Coordination with other Types

Visit to Submarine School

At U. S. Navy Underwater Sound Laboratory

Wednesday, June 21

Cdr. A. E. Krapf, CO	Welcoming Remarks
Dr. John M. Ide	General Outline of Technical Program
Mr. G. S. Harris	Introduction to Submarine Sonar Program
Mr. G. S. Harris	Systems Development
Mr. G. S. Harris	Long-Range Listening Arrays
Mr. R. I. Mason	Underwater Communications
Mr. H. E. Nash	Surface-Vessel Sonar
Mr. W. A. Downes	Torpedo Detection

Wednesday, June 21 (cont.)

Mr. C. M. Dunn	Submarine Radio Communication Problems
Mr. G. M. Milligan	Infrared Developments
Dr. J. Warren Horton	Applied Research

III. VISITS AND VISITORS

At the conclusion of the Briefing, the Group assembled at the Lexington Field Station of the Massachusetts Institute of Technology. There studies were initiated and discussions held. During July and August, a large number of persons visited the Project to advise, to furnish information, and to comment on tentative conclusions. In the working plan, the Hartwell practice was to "summon" experts in any field under immediate scrutiny, or to send small subcommittees to visit activities for information. The following list indicates the number of institutions and visitors to Hartwell prior to the September terminal meeting.

Air Force, Cambridge Laboratory

H. F. Dannemann
A. C. Goss, Jr.
L. M. Hollingsworth
J. Marchetti
S. B. Welles
P. A. dePaulo

American Airlines

D. S. Little

Bell Telephone Laboratories

M. J. Kelly

British Joint Scientific Mission

Sir Charles Wright
E. G. Hill

Brookhaven National Laboratory

G. B. Collins
J. B. H. Kuper
L. J. Haworth
G. F. Tape

Bureau of Aeronautics

C. M. Bolster
I. H. Driggs
E. W. Harrison
G. C. Miller

Bureau of Ships

W. H. Dix
P. G. Comens
L. M. Treitel
C. L. Engleman
F. S. Knight
S. H. Gimber

Colby Steel Company

J. Isaacs

Engineering Research Associates, Inc.

H. F. Engstrom

Federal Telecommuncations Laboratories

J. L. Allison

Lockheed Aircraft Corporation

W. W. Lindsay, Jr.
R. A. Bailey

Massachusetts Institute of Technology

E. L. Bowles

National Research Council

J. S. Coleman

Naval Research Laboratory

M. Katzin
J. R. Gruber

Operations Evaluation Group

J. Steinhardt
S. K. Shear
W. E. Albertson

Office of Naval Research

E. R. Piore
T. A. Solberg
A. J. Pleasants
R. Berheman
S. H. Pattie
R. K. Laughlin
M. C. Barstow
B. Holland
T. J. Killian
C. L. Murphy
G. C. Ewing
G. G. Lill
J. A. Krauss

Office of Naval Research (cont.)

C. B. Laning
U. Liddel
R. W. Hart
R. Holden
A. L. Powell
J. B. Pearson
F. J. Burr
E. E. Ross
A. Addelson
C. F. Muckenhaupt
J. W. Sheetz
C. L. Westhofen
V. F. MacCormack
R. W. Rohrman
R. M. Isaman

Operations Research Office

E. A. Johnson

Philco Corporation

D. Sundstein
G. J. Laurent

RAND

J. I. Marcum

Research and Development Board

W. Webster

Scripps Institute of Oceanography

R. Revelle

United Fruit Company

Hartley Rowe

University of Illinois

F. W. Loomis

University of Wisconsin

R. Rollefson

U.S. Naval Underwater Sound Laboratory

A. E. Krapf
J. M. Ide
H. Nash

Woods Hole Oceanographic Institute

A. C. Vine

Weapons Systems Evaluation Group

G. Welch
H. P. Robertson
H. Rivers
W. S. Parsons
L. Alaoglu
A. B. Vosseller

Whenever it was impractical to call experts to Lexington, various groups of Project personnel visited outside organizations where accurate, up-to-date information relating to specific fields of study could be obtained. The following institutions were visited by the Hartwell staff.

Atomic Energy Commission
Bell Telephone Laboratories
CinCLant
Federal Telecommunications Laboratories
Key West
Maritime Administration
Naval Ordnance Laboratory
Navy Department (CNO) and Bureau Chiefs
Office of Naval Research
Operations Evaluation Group
Philco Corporation
Woods Hole Oceanographic Institute

Available to the Hartwell Project was a library of classified documents. This library was secured through the assistance of ONR, and contained all publications recommended to the group by those concerned with the briefing.

A tentative draft of the summary was prepared on 28 August. This was discussed with many representatives of the bureaus and other agencies. A revised tentative draft was prepared 31 August which was discussed in detail at a Terminal Meeting on 1 and 2 September. This Terminal Meeting was attended by the Hartwell Group and the visitors in the following list.

Mr. D. A. Kimball	Under Secretary of the Navy
Admiral F. P. Sherman	Chief of Naval Operations
Vice Admiral F. S. Low	DCNO (Logistics)
Lt. Gen. J. E. Hull	WSEG
R.Adm. R. P. Briscoe	ACNO (Readiness)
R.Adm. C. B. Momsen	ACNO (Undersea Warfare)

R. Adm. W. S. Parsons	WSEG
R. Adm. T. A. Solberg	ONR
Capt. K. T. Poehlman	ONR
Cdr. J. W. McConnaughlay	USN (Aide to Mr. Kimball)
Cdr. C. L. Murphy	ONR
Lt. Col. J. L. Smith	USMC (Aide to Adm. Sherman)
Mr. Leonidas Alaoglu	WSEG
Mr. J. S. Coleman	NRC
Mr. G. P. Harnwell	University of Pennsylvania
Mr. M. J. Kelly	Bell Telephone Laboratories
Mr. J. R. Killian, Jr.	M.I.T.
Mr. F. W. Loomis	University of Illinois
Mr. E. R. Piore	ONR
Mr. H. P. Robertson	WSEG
Mr. W. Shockley	Bell Telephone Laboratories
Mr. J. Steinhardt	OEG
Mr. J. A. Stratton	M.I.T.
Mr. A. T. Waterman	ONR
Mr. William Webster	Chairman, Research and Development Board
Mr. G. I. Welch	WSEG
Mr. M. G. White	Princeton University

At these meetings, many suggestions as to form and content were submitted, which have been incorporated in the Report. This now represents, in essence, the material presented and discussed on 1 and 2 September.

APPENDIX L

HARTWELL GROUP SCIENTIFIC PERSONNEL

PAUL ADAMS - Head of the Navigation Division of Federal Telecommunications Laboratories. During and since the war has done extensive work on direction-finding systems and air-navigation systems.

LUIS W. ALVAREZ - Professor of Physics, University of California, Berkeley. During the war, was head of the Special Systems Division of Radiation Laboratory, M.I.T., and later worked on atomic bomb development at Los Alamos.

LLOYD V. BERKNER - Department of Terrestrial Magnetism, Carnegie Institution of Washington. During the war, was Director, Electronic Materiel Branch, Bureau of Aeronautics.

HARVEY BROOKS - Gordon McKay Professor of Physics, Harvard University. During the war, worked for OSRD at Harvard Underwater Sound Laboratory.

BERNARD F. BURKE - Research assistant, M.I.T.

EDWARD L. COCHRANE - Vice Admiral USN (ret.), Head of Department of Naval Architecture and Marine Engineering, M.I.T., and is now on leave as Chairman of Maritime Board. During the war, served as Chief of the Bureau of Ships.

EDWARD E. DAVID - Research associate, M.I.T.

CHARLES R. DENISON - Engineering consultant on port development and construction; recent project engineer, Port of Boston Authority; and port development research engineer, U.S. Maritime Commission; wartime colonel, Corps of Engineers, engaged on wartime port work in U.S. and Europe.

ROBERT H. DICKE - Associate Professor of Physics, Princeton University. During the war, was a staff member of Radiation Laboratory, M.I.T.

HARRY DREICER - Student, M.I.T.

CARL ECKART - Professor of Geophysics, Scripps Institute of Oceanography; Director, Marine Physical Laboratory, University of California. During the war, was associate director of the Division of War Research, University of California, at San Diego.

FRANCIS L. FRIEDMAN - Assistant Professor of Physics at M.I.T. During the war, worked at the Metallurgical Laboratory of the University of Chicago on atomic reactor developments.

HARALD T. FRIIS - Director, Radio Research, Bell Telephone Laboratories (Holmdel).

IVAN A. GETTING - Professor of Electrical Engineering at M.I.T. During the war, served as head of the Division on Radar Fire Control, Radiation Laboratory, M.I.T., and as consultant to Division on Fire Control, NDRC.

WILLIAM H. GROVERMAN - Commander USN. Head of Undersea Warfare Branch, Office of Naval Research. During the war, commanded the destroyers USS PHILIP and USS DEHAVEN and served on staff of Commander Destroyers Atlantic Fleet as Anti-Submarine Warfare and Combat Information Center Officer.

ALBERT G. HILL - Professor of Physics and Director, Research Laboratory of Electronics, M.I.T. During the war, was Chairman of the Radio Frequency Components Group and later the Transmitter Components Division of Radiation Laboratory, M.I.T.

MALCOLM M. HUBBARD - Assistant Director, Laboratory for Nuclear Science and Engineering, M.I.T. During the war, was in charge of Component Engineering at Radiation Laboratory, M.I.T.

FREDERICK V. HUNT - Professor of Physics, Chairman of Department of Applied Physics and Engineering Science, Harvard University. During the war, was director of the Harvard Underwater Sound Laboratory.

J. WALLACE JOYCE - Head, ASW Section, Radar Branch, Electronics Division, Bureau of Aeronautics.

WINSTON E. KOCK - Bell Telephone Laboratories. During the war, worked on microwave antenna development at BTL; Research Engineer on acoustical problems since 1948.

CHARLES C. LAURITSEN - Professor of Physics, California Institute of Technology. During the war, led a group in torpedo and rocket development, and took an active part in the atomic bomb project at Los Alamos.

J. C. R. LICKLIDER - Associate Professor of Electrical Engineering, M.I.T. During the war, worked at Psycho-Acoustic Laboratory of Harvard.

HAROLD S. MICKLEY - Associate Professor of Chemical Engineering, M.I.T. During the war, was project leader of a torpedo power plant development program under NDRC.

PHILIP M. MORSE - Professor of Physics, M.I.T., and consultant to the Weapons Systems Evaluation Group. During the war, established and directed the Operational Research Group of OSRD.

ARNOLD NORDSIECK - Professor of Physics, University of Illinois. During the war, was a member of the scientific staff of Columbia Radiation Laboratory and of Bell Telephone Laboratories, specializing in microwave electronics.

JOHN A. PIERCE - Research Fellow of Harvard University. During the war, was head of LORAN Division of the Radiation Laboratory, M.I.T.

RALPH K. POTTER - Director of Transmission Research, Bell Telephone Laboratories.

EDWARD M. PURCELL - Professor of Physics, Harvard University. During the war, was Chairman of the Advance Development Group, Radiation Laboratory, M.I.T.

RICHARD B. ROBERTS - Staff Member, Department of Terrestrial Magnetism, Carnegie Institution of Washington. During the war, worked on proximity fuses; head of fire-control group and guided-missile group (Bumblebee) at Applied Physics Laboratory, Silver Spring, Md.

MERLE A. TUVE - Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington. During the war, was Director, Applied Physics Laboratory, Johns Hopkins University, and Fire Control Division, NDRC.

FOSTER L. WELDON - Staff of Naval Ordnance Laboratory, working on mine warfare. Now with Weapons Systems Evaluation Group.

JEROME B. WIESNER - Professor of Electrical Engineering and Associate Director, Research Laboratory of Electronics, M.I.T. During the war, was leader of the Cadillac Project, Radiation Laboratory, M.I.T., and later head of the Electronics Division at Los Alamos.

JERROLD R. ZACHARIAS, CHAIRMAN - Professor of Physics and Director, Laboratory for Nuclear Science and Engineering, M.I.T. During the war, served as head of the Transmitter Components Division, Radiation Laboratory, M.I.T., and later was Leader of the Engineering Division at Los Alamos.

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Massachusetts Inst. of Tech., Cambridge pidc U

A REPORT ON SECURITY OF OVERSEAS TRANSPORT.
Project Hartwell, Vol 2 of 2. 21 Sep 50, 175p incl
illus, tables. Contract N6ori-07846

Military Sciences & Operations (18)	Warfare, Intercontinental
Logistics (3)	Logistics
	Ships, Cargo
	Harbors - Defense

(C~~opies obtainable from ASTIA-DSC by U.S. Military Organizations only.)~~

X Logistics Supp
Overseas
Physical Security

NTIS, Auth: ONR ltr, 14 Jul 77

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~~SECRET AUTH: DOD DIR 5200.10, 29 June~~

U Auth: ONR ltr, 14 Jul 77